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# THE RELATIVE TRANSPIRATION OF WHITE PINE SEEDLINGS[1]

GEORGE P. BURNS

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The study of plant ecology and the study of many phases of agriculture and forestry have emphasized most clearly the necessity for a scientific study of the habitat and the importance of the habitat upon the distribution and development of the plant.

The ecologist works with a group of plants which forms the society of plants in a given habitat. This society is named after one or more of the leading plants in the society—maple-beech, heath, *Carex filiformis*, etc. The plant society of the agriculturalist and the forester usually consists of one species or variety growing in larger numbers.

The ecologist attempts to work out the distribution of plants and to discover the laws which determine such distribution. He seeks to locate the present region where conditions are best suited for the development of any given species or plant. He has determined that the requirements in the habitat are more and more rigid the farther a plant gets from such region—its center of distribution.

Such data are of the greatest importance to the agriculturalist and the forester, as they indicate the possible regions of growth for any plant and would furnish the basis for planning experimental work.

Much of the work of the early ecologist has been descriptive, and the value of each contribution depends largely upon the training and ability of the individual writer—thus bringing in a very large margin of error.

A second group of contributions begins with a detailed and

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[1] Read at the Atlanta meeting of the Botanical Society of America, 1913.

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sometimes lengthy description of the meteorological conditions of the region under consideration. These are usually taken from the nearest station of the United States Weather Bureau, and include sunshine records, air temperature records, wind records, etc. The next section in these papers gives a detailed account of the plant societies of that region, their distribution, history of their development, facts concerning the water, etc., of the habitat, but one looks in vain for any important use of the data obtained from the Weather Bureau. The writer feels that there is a meaning, and feels it so strongly that he includes the data in his contribution, but he is at a loss to know what they mean in terms of the plant.

A third group of ecologists, realizing that they can not use to good advantage the data from the Weather Bureau, has attempted to gather their own data, limiting themselves for the most part to a study of evaporation. Many valuable data are being collected by this group of workers. The method consists, roughly, in determining the amount of water evaporated from porous cups in different habitats. These cups are usually placed near the surface of the ground even when determining the evaporation in forest societies.

A fourth group of ecologists is studying the effects of meteorological conditions on plant activities. Recording instruments for percentage of sunshine, percentage of humidity, air temperature, soil temperature, etc., are placed not at some high elevation above the plant society under consideration, but under the same conditions as those in which the plants are working.

For example, Livingston has attempted to determine the relation of the evaporation from the porous cup to the transpiration from a given plant. He believes that the porous cup is the best means yet devised for measuring the factors which influence evaporation. But such data of themselves are not valuable until the relation of the evaporation from the porous cup to the transpiration from the living plant can be determined. He, therefore, works out the sun-shade ratio for white, black and brown atmometers, and several plants. This, to my mind, is one of the most promising fields of research in ecological botany.

The final answer to questions raised by the ecologists can only be found by experimental work, as in any other line of botany.

During the past three seasons the writer has been studying the evaporation from porous cups placed in seed beds in the Vermont State Forest Nursery, and the present paper is an attempt to express the results of evaporation from the white and black atmometers in terms of transpiration from the seedlings of *Pinus strobus.*

It is not necessary to describe in detail the seed beds. The usual nursery bed was used. These are 12 feet long, 4 feet wide surrounded by a frame 1 foot high. Three kinds of covers were used. One was covered with wire; a second, half covered with lath; and a third, entirely covered with lath. In each bed were placed black and white atmometers. The amount of transpiration was determined by weighing plants which had been previously potted. The data recorded represents the result of 15 four-hour periods during the first half of August, 1913.

The effect of external conditions upon the various objects used in the experiments showed only a general agreement between evaporation and transpiration. In the no-shade, half-shade and full-shade beds the agreement of the atmometers was rather striking. In comparing the plants with the atmometers, it was seen that although the response was not similar, yet there was a closer relation between the black atmometer and plants than between the white atmometers and the plants.

Using the black atmometer as a basis for comparison, it was found that the relative transpiration (transpiration divided by evaporation) in the three beds was as follows:

| | |
|---|---|
| No shade | 0.0633[2] |
| Half shade | 0.0346 |
| Full shade | 0.0088 |

With these coefficients it is possible to calculate the transpiration from the white pine seedlings from the evaporation from a second set of black atmometers which had been running all season. Figured on this basis, from the beginning of the vegetation period to the time of the experiment it was possible to determine that the approximate amount of water transpired from each tree was as follows:

---

[2] In the report of the secretary of the Botanical Society given in Science New Series No. 998 p. 259 some of these values were out of order.

| | |
|---|---|
| No shade | 21 x cc. |
| Half shade | 8 x cc. |
| Full shade | x cc. |

That is, the seedling in no-shade used 21 times, and the seedling in half-shade used 8 times as much water as the one in full-shade.

The questions naturally arise which was the best tree, which had the greatest amount of ash, what was the chemical composition of these trees?

Trees harvested July 31 were about 8 to 10 weeks old. The average green weight of the trees based upon the weight of 500 seedlings in the case of the "no-shade" and "half-shade" trees and upon the weight of 1000 seedlings in the "full-shade" trees, was as follows:

| | *Green weight* | *Dry weight* |
|---|---|---|
| No shade | 0.304*g* | 0.063*g* |
| Half shade | 0.166 | 0.034 |
| Full shade | 0.090 | 0.010 |

The dry weight of the plant produced in "no-shade" was a little more than six times as great as that produced in "full-shade," and the plant produced in "half-shade" was almost three and a half times as heavy in dry weight as the "full-shade" plants only about one-half as heavy as the "no-shade" plant.

The ash content of the plants was next determined and is here given in percentage of dry weight only. This showed that the total ash content was:

| | |
|---|---|
| No shade | 8.29% |
| Half shade | 9.35% |
| Full shade | 10.20% |

The nitrogen content for the three trees in percentage of dry weight was:

| | |
|---|---|
| No shade | 2.18 |
| Half shade | 2.70 |
| Full shade | 6.89 |

These figures show that there was a difference in the material taken from the soil by the three plants.

Returning to the figures given for transpiration, it is seen that the plants which transpired the most water, the plants in no-shade beds, contained the smallest per cent of ash and that the plants which transpired only one-twentieth as much water contained the largest percentage of ash. Again taking the total amount of ash absorbed, it is seen that there is no very evident relationship between the amount of water absorbed and the amount of ash taken up, twenty times the water is accompanied by only five times the ash; eight times the water by three times the ash. The plants then are able not only to select the minerals which they take from the soil but also to control the degree of concentration of the solution which enters the root hairs.

Pfeffer in describing the experiment of Schlösing, who found that tobacco plants grown under bell jars did not grow as well as others, says "Though a variety of other factors enter into play here, such experiments suffice to show that transpiration favors the absorption of the constituents of the ash." This statement should be closely questioned—when applied to our pine seedlings. Oven has shown that even a clear glass cover greatly increases the nitrogen content and from the fact that the plants in full-shade and half-shade beds already have a surplus of ash over the no-shade or normal plants, it seems highly probable that some of the other factors may be more important in determining the amount of ash absorbed. The lack of growth of seedlings in full-shade cannot be due to lack of water or the amount of ash. Lubiminko remarks that pea pods grown in the dark seem to have a higher percentage of ash. He associates the percentage of ash with light rather than transpiration. According to the work of Pagnoul and Oven, the nitrogen content of sugar beets and potatoes increase as much as ten times when plants are grown in the shade. Oven associates this with absorption and assimilation and Pagnoul says that in the shade the nitrogen salts cannot be used.

The data on white pine show no such great differences in nitrogen content in the no-shade and full-shade trees. White pine seedlings contain only about three times as much nitrogen when grown in the full-shade.

The data given in this paper indicate that the explanation of the differences in size and chemical composition of the three groups of trees must be sought along the line of photosynthesis and assimilation rather than along the line of absorption and transpiration.

# AN IMPROVED NON-ABSORBING POROUS CUP ATMOMETER

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Since Livingston's[1] description of the rain correcting atmometer appeared in 1910, a large number of these instruments have come into use. Up to the present time, however, the instrument has had the disadvantage of not being self-contained. The automatic mercury valves which operate to prevent the water, absorbed by the porous cup in times of rain, from entering the reservoir, are externally situated. This renders the valves liable to breakage and rather difficult of adjustment. For this reason it seemed well to modify the instrument in such a way as to be self-contained and at the same time to reduce the liability of breakage and the difficulty of adjustment to a minimum. With this end in view the present form of the instrument was devised.

The arrangement of the different parts of the instrument is shown in diagram in figure 1. From the reservoir ($F$) two glass tubes ($A$ and $B$) extend upward through a paraffined cork stopper, and then through a two-perforate rubber stopper into the porous cup, one passing to the tip of the cup, the other just to the upper surface of the rubber stopper. These tubes are of small bore, about 0.8 mm. inside diameter. Each is bent into a *U* and continued upward as $A'$ and $B'$. One ($A'$) extends through the paraffined cork stopper and ends about 5 cm. above it. The other ($B'$) extends upward 6 cm. to 8 cm. and is again bent into a *U* (inverted), thus forming a loop, and terminates near the bottom of the reservoir. The tube $B$ is expanded into a small bulb $C$, at its lower extremity, and the tube $A'$, is expanded into a similar bulb 1 cm. to 2 cm. from its lower end. The tube $E$,

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[1] Livingston, B. E., A rain-correcting atmometer for ecological instrumentation. Plant World **13**: 79–82, 1910.

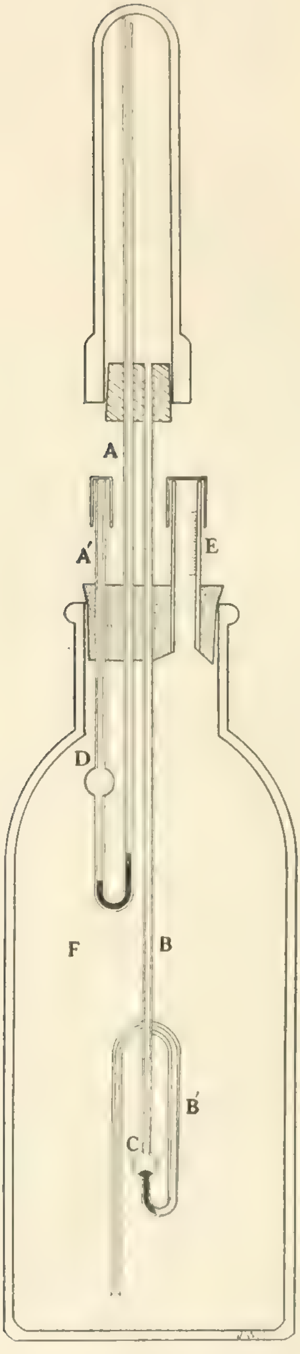

Fig. 1.

is about 1.2 cm. in diameter, and forms a shallow, inverted funnel with the lower surface of the paraffined cork stopper. This serves to conduct air bubbles, which may catch on the under surface of the stopper in filling the reservoir, to the exterior. The tube extends 5 cm. above the cork stopper, and is graduated to tenths of cubic centimeters. The zero point on the tube serves as a zero point in filling the reservoir.

To install the instrument the paraffined cork stopper, into which the tubes *A A′*, *B* and *E*, have been properly fitted, is tightly appressed into the mouth of the reservoir *F*. A sufficient amount of clean mercury is allowed to fall from a pipette into the openings in the upper end of each of the tubes *A′* and *B*, to form a column 5 cm. to 6 cm. high in tube *A′*, and slightly more than this in tube *B*. After the porous cup has been placed in position and the reservoir filled with distilled water, a rubber tube is attached to the free end of the filling tube *A′*, and gentle suction is applied. Water rises from the reservoir into the tube *B′*, at the same time that the mercury in this tube is drawn into the bulb *C*, where water passes freely and rises in the tube *B*, filling the porous cup. When the cup is filled water passes into the tube *A A′*, the mercury in this tube having been drawn into the bulb *D*, where the water is allowed to pass freely and escape into the rubber tube, which is then removed. The mercury in the bulbs *C* and *D*, drops back into the tubes below. To prevent water loss from the reservoir by evaporation through the tube *E*, and to prevent the entrance of water through this tube from without in times of rain, a vial is placed over the end of this tube. A suitable vial is also placed over the end of the tube *A′*, to exclude dirt. The instrument is now ready for operation.

To replace the cup with a new one it is only necessary to remove the old cup from its support and to place the new cup into position, after which suction is applied to the tube *A′*, as in installing.

As water evaporates from the surface of the cup, the mercury rises in tube *A*, and falls in tube *A′*, coming to rest with the mercury level in *A*, slightly higher than in *A′*, the difference in the height of the two columns depending upon the height of the cup above the water level in the reservoir. The mercury in *B B'*, is drawn into the bulb *C*, where water rising from the reservoir is freely allowed to pass, supplying, in the usual way, the water lost from the surface of the cup. The mercury columns in the tube *A A'*, and *B B'*, remain in equilibrium in the position indicated in figure 1, so long as the water loss from the surface of the cup by evaporation equals or exceeds the absorption from without by any part of its surface. In times of rain, when the water loss from the surface of the cup by evaporation is less than the absorption from without, the automatic mercury valves become reversed. The mercury column falls in *A*, and rises in *A'*, at the same time that the mercury in bulb *C*, drops into the tube below and rises in the tube *B'* (the height to which the mercury rises in this tube depending upon the height of the cup above the water level in the reservoir), thus effectually preventing water from entering the reservoir from this direction. The readings obtained give the actual evaporation minus the error introduced by the volume change required for the operation of the mercury valves, the value of the error thus introduced depending upon the number of complete reversals of the valves.

Harvey[2] has estimated the error permitted by the Livingston mercury valves to be no greater than 0.01 cc., assuming the glass tubing used to have an inside diameter of approximately 0.8 mm. and assuming the cup to be not more than 30 cm. above the water level in the reservoir. In the present modified form of the instrument the volume change required for the operation of the automatic mercury valves is no greater than that estimated by Harvey. It is evident, therefore, that the error involved in one or several complete reversals of the valves is quite negligible excepting in cases where extreme accuracy is essential.

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[2] Harvey, E. M., The action of the rain-correcting atmometer. Plant World **16**: 89–93, 1913.

# A MANOMETER METHOD OF DETERMINING THE CAPILLARY PULL OF SOILS

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The apparatus to be briefly described has been in use by the writer at the Desert Laboratory for two years and has been found of service as a convenient means of determining the capillary pull of soils used in experimental work. No attempt is here made to relate the results to be given with results achieved by using the direct method of measuring the ascent of water, which is the method commonly employed. Whether the results of the two means of determining the capillarity are comparable, as they possibly are, is not germane to the present purpose.

As used the apparatus is very simple and can be put together in a few minutes in any laboratory. It consists, in brief, of a U-shaped mercury manometer, with open ends, and a soil container holding about 500 cc., and, in addition, a reservoir of about 500 cc. capacity for water. The reservoir is connected with a T-shaped glass tube having a three-way cock. A rubber tube connects one free end of the T-tube with the manometer, and another rubber tube, which should be relatively long, connects the third end of this tube with the soil container. The various portions are easily attached by clamps to a horizontal iron rod which is fastened to a ring-stand.

When the several parts of the apparatus are assembled water is put in the reservoir and the whole is so manipulated that water, to the exclusion of any air, fills the tubes which unite the container, the reservoir, and the manometer. The reservoir and the container are about on the same level so that, if the cocks are left open, water will stand equally near the upper edges of both.

After the rubber tubes and the uniting glass tubes are filled with water the reservoir should be somewhat more than half full. With the cocks joining the reservoir and the container open, so that water may flow between the two, the container is raised or lowered sufficiently to bring the water in it to a depth of about 2 cm. when the cocks are closed. A small plug of glass wool is put in the bottom of the container, to prevent the escape of the soil, and all air is removed from the wool by gentle packing. The apparatus is then ready for the introduction of soil.

The actual manipulation, so far as is necessary to give it in detail, is as follows: The container is filled with soil. The cocks are open, permitting the rise of water and its flow out of the reservoir, and the soil is at once run through several times with a small glass rod. The last operation is for the purpose of promoting the settling of the soil as well as to prevent the premature collecting of air bubbles at the bottom of the soil container. All of this time, it should be understood, the water is flowing freely from the reservoir into the container and is rising in the soil. As soon as the soil appears to be uniformly settled the cock beneath the reservoir is so turned as to cut off the flow of water from it and, at the same time, to connect the container with the manometer. The position of the mercury is observed at this moment and the rise is watched until the upward movement ceases, or until the mercury falls. The uppermost point reached by the mercury is considered the measure of the capillary pull of the soil under the conditions of the test.

When the mercury falls the experiment is ended. If it is desirable, as it generally is, to repeat the test, and if *there are no air bubbles in the bottom of the soil container*, it can be done in one of two ways. Either the soil can be removed and the test begun anew, as must happen should air be found in the bottom of the container, or the following manipulation can be resorted to. Water is immediately run into the container and the soil is run through with a glass rod, after which the water is turned off and the position of the mercury noted and its rise observed as before. This operation can usually be repeated several times before the collection of air bubbles in the bottom of the soil compels the termination of the test.

As illustrating typical results the following experiments can be cited. Tests of sand, and of adobe, separate and mixed, were made. When mixed, equal parts of each were taken. In all cases the largest soil particles, or, more exactly, intrusions, like small pebbles, were removed by passing the soils through a coarse sieve. After this each kind of soil tested was separated into two parts by sifting through sieves of two sizes, namely, 20-mesh and 40-mesh (that is, 20 and 40 meshes to the inch). Repeated tests were made in every instance. For the mixed soil, the highest point reached by the mercury was 22.5 mm. The 20-mesh sand registered 6 mm., and the 40-mesh sand, 9.5 mm. Unsifted adobe, 20-mesh, stood at 18 mm., and 40-mesh, 25 mm. The capillary pull of the sifted adobe soil is not easily determined, owing, probably, to its peculiar physical nature. An interesting and characteristic quality of the tests with sand, especially the coarse sand, is that the mercury rises very quickly at first, but for a brief time, after which it maintains an even height for a long period. For example, the mercury in a test with 40-mesh sand remained at 9.5 mm. for over three hours.

Other results might be given as well, but those presented are sufficient to show the behavior of the soils mentioned as regards the quality in question. It is recognized that the method is not without theoretical, and, possibly, practical objections. Of these, possibly the most serious is the inevitable difference between soils, even of the same kind, when treated in such tests, as regards their compactness. To this it can be suggested that settling under water, and parallel treatment otherwise so far as possible, makes the objection possibly less serious for this method than for other methods. The objection holds, in other words, quite as well for the direct observation of the capillary rise of water in soils. Errors from such a source, in the manner of determining the capillary pull in the way here described, can be minimized also by making the tests several times, and under parallel conditions of temperature, which is not feasible by the direct method referred to. Finally, the manometer method commends itself as a convenient and striking means of demonstrating an important physical characteristic of soils, whether, which is unimportant, it is an entirely new method or not, and independent of the probability that it is theoretically not ideal.

# BOOKS AND CURRENT LITERATURE

THE SALTON SEA: GEOGRAPHY AND GEOLOGY.—Monographs such as The Salton Sea[1] are typical of the spirit of coöperation which is a dominant tendency of modern science. Dr. MacDougal has associated with himself no less than nine collaborators, each of whom deals with a distinct subject, but all of whom cooperate to give a comprehensive picture of a unique region. It is fortunate for science that when the Colorado River last overstepped its bounds and made a new lake, the Desert Laboratory of the Carnegie Institution was ready to investigate the complex and important changes, both geographical and botanical, which have since ensued.

In its geographical and geological portions the book centers around three main points, namely, the nature of the Cahuilla Basin, its unique departures from the typical features of a desert basin, and the relation of low forms of life to the production of tufa. The opening chapter is most fittingly allotted to Professor W. P. Blake, the first scientist to describe the region. The ancient lake which once occupied the Salton Sink and rose to about 40 feet above sea level before overflowing to the Gulf of California has been named Blake Sea in his honor. He discusses its geological history. The Cahuilla Basin in which it is located is a structural trough, the continuation of the Gulf of California. According to Professor Blake's view, which has hitherto prevailed almost unchallenged, the upper end of the trough, forming the part now known as the Salton Sink, was a part of the Gulf until recent geological times. Then it was gradually cut off by the growth of the delta of the Colorado River. Above the delta the isolated end of the Gulf formed a salt lake which eventually dried up and disappeared. From time to time, however, a diversion of the Colorado River, such as occurred in 1905, produced a temporary body of fresh water. According to this interpretation the Salton region possesses few of the characteristics of a genuine desert basin.

The next contributor, Mr. Sykes, accepts Professor Blake's view.

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[1] The Salton Sea: A Study of the Geography, the Geology, the Floristics, and the Ecology of a Desert Basin. 4to, pp. xi + 182, pls. 32, maps 2. Carnegie Inst. Washn. Publ. 193. 1914.

His chapter describes the general surface features of the country, and discusses its exploration and early mapping. It forms the natural introduction, and would have been placed first except for the desire to pay a graceful tribute to Professor Blake's pioneer explorations. The next chapter, by Mr. Free, goes further into the question of the origin of the ancient lake and the general character of the basin. A series of Tertiary strata, now uplifted and folded, lies at the foot of the surrounding mountains. This formation is clearly of subaerial origin, a piedmont deposit washed down from the highlands under conditions of aridity. It indicates that for a long time during the Tertiary era the basin was not occupied by the sea, and was essentially like the other basins of the Southwest. In far more recent times, that is within the last few thousand years, the basin has also been free from the sea, for innumerable shells show that it was occupied by fresh water. Moreover, the strands of Blake Sea, which may date back no more than 500 years indicate a very brief stand of the lake at the level of overflow. If an arm of the sea were cut off, the water must have stood at an approximately uniform level for many centuries while the delta was being formed, and there ought to be a pronounced bench in the rock, but none is found. Hence Free suggests that the whole region may have been above sea level for a long period. At first it was a simple trough. This was gradually depressed, but the delta of the Colorado was built up as fast as the land sank and a genuine basin was thus formed in its rear. This was occupied by water only when the Colorado temporarily shifted its course. Aside from exceptional periods of this sort, the Salton region appears to have had a history like that of the typical desert basin. Free's interpretation needs further study, but it seems likely to prevail.

The relation of the Salton tufas to organic life suggests that the chemical deposits of interior basins can be understood only by a study of the effect of different types of bacteria or algae upon chemical reactions. Papers by Ross and Vinson give details as to the concentration and composition of the water of the Salton Sea at frequent intervals since the last inundation. Pierce follows with an interesting account of micro-organisms in highly concentrated brines. He shows that living algae are found in water of a surprisingly high degree of salinity, and that their activity varies in harmony with changes in the degree of concentration. Brannon considers another phase of the same matter. He immersed pieces of wood in Salton water for long periods. When the water was sterilized, little decortication took place. Chemical activity seems to depend upon the presence of certain bacteria, some of which were isolated. Jones confirm this conclusion by showing that both now and in the past the Salton tufas have been deposited only in the presence of algae. The presence of minute organism, is probably of much more importance chemically than has commonly been realized. In this respect and in other ways this monograph on The Salton Sea is likely to prove of great value in stimulating new lines of thought.—ELLSWORTH HUNTINGTON.

THE SALTON SEA: FLORISTICS AND ECOLOGY.—The papers of Parish and MacDougal occupy more than half of the Salton Sink volume. They give, detailed and in broad lines, answers to many questions of great interest concerning desert vegetation as a whole, the biology, dispersal and wandering of its plants, the relation of a sink to surrounding elevated land masses and especially concerning revegetation of bared land, the means which enable plants to get a foothold and the causes which make them again disappear. The latter part of the book, MacDougal's treatment of the revegetation of the beaches, is the principal one, giving as it does a vivid picture of movement and activity in nature under almost unique conditions.

The paper of Parish shows us, as it were, the stage upon which the play is performed, or the ordinary order of things undisturbed. So we learn that the Salton Sink with its *Atriplex* vegetation is bordered on both sides by zones of more or less related vegetations of which the *Opuntia* zone is especially interesting, showing the curious feature of cacti living on the rim of the Sink without entering it.

The Sink flora of which a very careful list is given, numbering 200 species, including sporophytes, is a part of the Colorado desert flora which is the western fringe of the arid lower Sonoran flora; from the southeast to the northwest species drop out successively, so we understand that the conditions of the Sink are very exclusive; only 122 species are indigenous. These are tabulated with regard to ecological classes, 51 are annuals, 30 perennial herbs, 23 shrubs, etc., numbers which indicate desert conditions, as emphasized elsewhere by the present writer.

The factors in control of distribution are the chemical and physical character of the soil and especially its water content; of the formations accordingly established by Parish the xerophytic formation occupies an area exceeding the combined areas of all the other formations; its main plants are: shrubby *Atriplices*, *Prosopis*, *Cercidium*, *Parosela*, *Olneya*. As general characteristics of the xerophytic formation Parish states that shrubs and suffrutices are prevalent but only in few species, the individual plants are separated by large intervals, have a condensed growth and small, often early deciduous leaves. There are no succulents at all. Induments have not been evolved to any marked degree, and there are only two species with storage roots. Seedlings of the desert shrubs have never been found (except of *Parosela*) although the seeds are known to be able to germinate readily.

In MacDougal's paper it is described how the plants move onto the beaches as these are laid bare. The lake receded in 1907–1912 from 40 to 59 inches yearly, but the breadth of the emersed beaches varied of course with the angle of their slope. This angle also determines the duration of the wet stage of the newly emersed beach, steeper slopes desiccating faster than gentle ones, and this condition again determines the alkalinity.

For the study of the differences of the beaches five areas were selected, of which two only need be named here, viz., Imperial Junction with a slope 1 in 300, and Travertine Terraces with a slope 1 in 20. The latter locality had a gravelly soil in which the waves cut banks during each winter when the evaporation was slight and the lake consequently receded slowly.

All the areas were often visited during the years 1908–1913, every change in the conditions was noted and every plant was followed from seedling to death or to perfect establishment.

Although propagating bodies of hundreds of species must have been carried into the lake by wind or water only 60 species in all appeared on the beaches. Most of these were species inhabiting the lower parts of the basin above water, but there was also a number of introduced species and some species native to the valley of the Colorado River. Comparing the beaches in the same place we find a considerable variation in number and composition of introductions in the different years, suggesting differences in the dispersing agencies (wind) during the time when seeds were ripe for dispersal. During later years some species are dropping out from the pioneer class, which fact is ascribed to the effect of the increasing amount of chlorine in the water of the lake.

The beaches of the different areas studied had in part different pioneers. For instance, at Imperial Junction *Atriplex fasciculata, Spirostachys, Suaeda and Scirpus paludosus* were common pioneers, rare or absent at Travertine Terraces, where *Distichlis*, *Salix* and *Populus* were establishing themselves in numbers.

Also numerically there was a difference: the first named locality with its gentle alkaline slowly desiccating slopes presenting better opportunities for germination had a greater number of pioneers than Travertine Terraces.

On the other hand very few pioneers were able to maintain themselves when the beaches were drying out. Thus, at Imperial Junction, the number of species was reduced from 17 in 1907 to 5 in 1912, and here no secondary introduction took place. At Travertine Terraces the reduction in number of pioneers was counteracted by secondary introductions of more or less xerophytic plants. Still, nowhere had the beaches reached a stable condition, equivalent to that in which they had been before the making of the lake.

Of the species appearing on the beaches about 80 per cent might have been brought by wind, but only 12 per cent could *only* have been brought by wind. Of other agencies, birds have probably played a rôle, and some instances were found where ephemeral run-off streams had carried species down from the land above. Flotation played a very important part in the transportation of seeds; flotsam collected at the water side gave a number of seedlings. MacDougal has tested a number of seeds in the laboratory, keeping them in Salton water and observing the duration of flotation and the germination. The plantlets were also "stranded" in imitation of the probable action in the lake. It came out that "in 10 of the 15 species tested the flotation period of the seed, which in the different species may be from a day or two to four months or more, may be followed by the survival of the plantlet for periods of such length as to render them liable to be carried about by many agencies." Thus buoyant plantlets may remain in the surface of the water for a long time and finally strike root on the beach. Inferential as this reasoning is it gives us the doubtless true but somewhat paradoxical conception of plant-dispersal by water in desert areas. This is beautiful evidence that "the origination of qualities or structures upon which dissemination would depend, in many instances at least, has no possible connection in a causal way with the agencies themselves" (quoted from MacDougal's "general discussion").

To this short review must be added congratulations to the authors for the publication of this magnificent volume, pleasing by its fine appearance, by its many beautiful plates, and attractive on account of the great interest attaching to the subject, the systematic manner in which the investigation has been begun and carried out, and the thorough treatment of the whole result of the investigation. As true naturalists the writers have not concealed the shortcomings in their investigation—let us hope that still existing problems will provoke continued publications on the Salton Sink.—OVE PAULSEN, COPENHAGEN.

PERIODICITY IN TREES.—Rhythm and periodicity may not be so much a part of the life of the plant as has been taken for granted by physiologists. The beech has been cited for many years as imperturbable in its resting period, and not to be awakened during the winter time by any high temperature exposures, ether threatment, etc. Professor Klebs[1] of Heidelberg has been able, however, to maintain the European beech (*Fagus silvatica*) in continuous growth during the winter, and concludes that the countless experiences of the species with alternating favorable (summer) and unfavorable (winter) seasons have made no permanent impress on the organism in the way of an acquired rhythm. Confirmatory results with oak, ash, and hornbeam were obtained. Professor Klebs used a small enclosed chamber in a dark room, illuminated by tungsten lamps of a total intensity of 200 candle power, and the entire dark room with 1000 candle power. Moisture and temperature control and registration were secured.—D. T. MACDOUGAL.

TROPICAL SILVICULTURE.—Under the title of Sylviculture in the Tropics, Broun[2] incorporates in one volume a discussion of the problems of silviculture as applied to the tropics. The author frankly states that had he undertaken the publication on his own accord he would have restricted its application to the portions of the tropics and of the sub-tropics in which he had gained his experience. The author's work in India, Ceylon and Soudan is utilized to make many practical applications. Aside from this the publication does not offer anything new to the art of silviculture. H. N. WHITFORD, CANADIAN COMMISSION OF CONSERVATION.

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[1] Klebs, G., Über das Treiben der einheimischen Baüme, speziell der Buche. Abh. d. Heidelb. Akad. d. Wiss. Math-Naturw. Kl. 3 Abhandl. 1914.

[2] Broun, A. F., Sylviculture in the Tropics. Pp. 309, figs. 96. Macmillan and Company, 1912 ($3.00).

# NOTES AND COMMENT

Dr. Marshall A. Howe, of the New York Botanical Garden, has published a paper on the marine algae of Peru, based chiefly on collections made by Dr. Robert E. Coker while investigating the fisheries resources of that country. The waters of the Peruvian coast are temperate except at the extreme north, and are inhabited chiefly by temperate and sub-tropical algae, among which gigantic members of the Laminariaceae are conspicuous. Dr. Howe's report is notable in that the collections of Dr. Coker, made incidentally to other work, have nearly doubled the known alga flora of Peru, and in the fact that the Peruvian Department of the Interior has aided in the publication of the sumptuously illustrated report, which forms Volume 15 of the Memoirs of the Torrey Botanical Club.

The Cambridge University Press announces the appearance of two new periodical publications. The Annals of Applied Biology is a quarterly organ of the Association of Economic Biologists, devoted chiefly to pathology, horticulture, forestry and tropical economic botany. The Annals of the Bolus Herbarium is edited by Professor H. H. W. Pearson and is devoted to taxonomic, ecological, and other botanical work emanating from South Africa.

The New York State College of Forestry at Syracuse University announces the establishment of an Eastern Forest Products Laboratory to be located in the State Forestry Building which will be ready for occupancy in the summer of 1915. In the State Forestry Building, for which the State appropriated a quarter of a million dollars, there will be nearly 14,000 square feet given up to experimental laboratories outside of laboratories especially for educational work with students.

# ATMOMETRY AND THE POROUS CUP ATMOMETER[1]

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## I

## INTRODUCTION

The importance of the porous cup atmometer in studies of plant and animal environment, and the fact that the literature of the instrument fails to present, in adequate manner, several very important considerations in regard to operation and interpretation of atmometric readings, have led to the presentation of this paper. For the sake of completeness it is here attempted to state all essential points as far as they have been worked out, whether or not such statement may involve repetition from the writer's earlier papers. In short, this publication aims to put before the worker in porous cup atmometry the various matters requiring his attention, many of which might not be appreciated without years of experimental acquaintance with the subject.

Since so many names for the atmometer have been proposed by various writers, it is perhaps not out of place here to state that the term now practically in general use was first employed by Leslie[2] in 1813. This word was adopted as official by the Committee on Evaporation of the Vienna Meteorological Congress in 1874. The committee emphasize the fact that the word atmometer "possesses the merits of seniority and a correct classical derivation." It is constructed on parallel lines with the familiar *barometer*, *thermometer*, *hygrometer*, *anemometer*, etc., and thus enters readily into climatological and meteorological discussion.

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[1] Botanical contribution from the Johns Hopkins University, no. 43.

[2] Leslie, J., A short account of experiments and instruments depending on the relations of air to heat and moisture. Edinburgh, 1813

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## ATMOSPHERIC EVAPORATING POWER AND ITS MEASUREMENT IN GENERAL

### *Conditions Controlling Evaporation*

This is not the place for a detailed discussion of evaporation and its controlling conditions, but enough space may be taken to point out certain features of evaporation and certain requirements of atmometric measurements in general. In the first place it is to be emphasized that the water surface from which evaporation proceeds is as truly a control of the rate of water loss as are the atmospheric conditions. This consideration at once frees us from the still prevalent idea that there is anything fundamental and absolute in evaporation rates obtained from a free water surface. To make this clear, assume a water surface of known area, the water held in a pan or tank of known volume, the surface being a known distance below the margin, and the material and form of the container being also defined. Further assume a certain complex of aerial conditions, wind, temperature, humidity. Under such conditions it may be found that water is lost from the exposed surface at a given rate per hour, which may be reduced to an hourly rate from unit of surface. Now let the water container be altered in size, all other conditions remaining the same, and we shall find that the rate of loss per unit of area is not the same as before. Let the area remain the same and let the form or material of the container alone be altered, and another change in rate of water loss occurs. Of course it is understood that the changes here supposed must be of adequate magnitude, otherwise the resultant differences in rate might not be detectable by the extremely crude methods usually employed for measuring the rate of water loss. *All the details* of the construction of the water pan must have their influence upon the rate of evaporation per unit of surface, under any given set of surroundings.

If, however, two instruments are assumed to be exactly alike, and if they be exposed to the same complex of external conditions, then the rates of loss should be the same. If, in this case, the external conditions to which two like pans are exposed be altered in the same way for both pans, then both rates of loss should change, but this change should be the same for both instruments.

A somewhat less obvious result follows if two *different* kinds of water pan are exposed first to one external complex and then to another. For such a case, let it be supposed that one instrument loses twice as much water per hour as does the other, under the first conditional complex. Under the second complex of external conditions this relation between the two rates of loss no longer holds; the first instrument does not then lose just twice as much as does the second. In other words, if one of these unlike pans be standardized to the other, the coefficient of correction (by which the loss from one pan may be multiplied, in order to give the loss from the other) would be different for each new set of external conditions.

It appears that the principle just dealt with is but vaguely appreciated by many students of atmometry, a conclusion reached by a perusal of the meteorological literature of evaporation; in spite of frequent publications establishing the influence of size, shape, etc., of pans used, workers in this field still persist in employing a variety of pans and tanks, thus rendering their measurements of but little lasting or generally comparative value. If it might be remembered that the evaporation rate depends upon the water surface and upon the *surroundings* of this surface (both below and above), then this misapprehension should be avoided.

From what precedes it is clear that no form of pan is any more a natural standard for measuring evaporation than is any other. When pans are to be employed in atmometry it is only essential that all pans be alike, if the measurements thereby obtained are to be compared. In any event, the pan used must be described in detail if the results are to be of any value to other workers.

Another consideration that appears worthy of emphasis here is this, that the exposure of several atmometers must be comparable if the readings are to be so. Thus, if one of two like pans be placed at ground level and the other at some elevation above the soil, there can be obtained therefrom no definite information as to the relative intensities of evaporation in the two localities, at the same level. It may be said only that the evaporating power of the air at one level in one locality bears such and such a relation to the same power at another level in the other locality. The exposure of an atmometer needs to be specified as much as does the nature of the instrument.

These points apply as well to other forms of atmometer as to the form employing a free water surface. Different sized paper disks on the Piche and Piche-Cantoni forms (with their horizontal, saturated papers giving off water both above and below) are also influenced in their relative rates of water loss by changes in wind, temperature, etc. It is also clear that the alteration of evaporation rate from any instrument employing paper may not be at all the same as the corresponding alteration for any free water surface, these alterations being both effected by the same change in external conditions. Thus it is obviously impossible to reduce Piche readings, for example, to terms of depth from a pan of water, though this has often been attempted. A coefficient for this reduction can of course be obtained *for any given set of external conditions*, but when the conditions alter we must expect the coefficient to alter also. Likewise, evaporation rates from different forms or sizes of porous clay cups are differently affected by the same alterations in the surroundings, and it is quite impossible to obtain a coefficient by means of which the readings of one form may be reduced to those of another, excepting with specified surroundings. Nor can porous cup losses be reduced to losses from pans or paper disks.

### *Reduction of Readings*

The apparent success which has sometimes appeared to attend attempts to derive coefficients for the reduction of evaporation rates from one form of atmometer to those from another form[3] has doubtless been largely due to the fact that the general period of observation employed involved such slight alterations in the effective surrounding conditions that the crude methods of measurement failed to detect the variations emphasized above. It is of course possible, also, that certain different changes of the external conditions might be found, which might happen to affect the rates of water loss from different forms of atmometer in the same way and to the same extent, but it is highly improbable that such changes are frequently to be encountered in the diurnal or annual march of atmospheric conditions anywhere in the world. Where only slightly refined measurements are made, and where the change in external conditions or the difference between the instruments lies within certain limits of nature and magnitude, it may frequently occur that the rates of water loss from one form of instrument may apparently agree in their fluctuations with those from another form. A closer study usually shows such agreement to be only apparent.

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[3] Russell, T., Depth of evaporation in the United States. Mo. Weather Rev. **16**: 235–239, 1888.

Livingston, B. E., The relation of desert plants to soil moisture and to evaporation. Pub. 50 of the Carnegie Institution of Washington. Washington, 1906.

The writer's own experience in this connection is of illustrative value here. When the porous cup was first employed in the study of plant transpiration (summer of 1904, at the Desert Laboratory; see Pub. 50 of the Carnegie Institution, already cited), the earlier literature of evaporation was not available and the now obvious mistake was made of supposing that the readings from the cup might be reduced to depth units as lost from a free water surface, without regard to alterations in external conditions. The data presented on page 28 of the publication just mentioned show clearly, however, just the sort of fluctuation in reduction coefficient, for different hours, that would be expected from the discussion just presented. Below the table of calibration data occurs the statement, "The fluctuations in the ratio are probably in large part due to the failure of slight air currents to accelerate evaporation from the dish as much as they

—— Operation of the porous cup atmometer. Plant World. **13**: 111–118, 1910.

Many other instances of similar sorts are cited in: Livingston, Grace J. An anotated bibliography of evaporation. Mo. Weather Rev. **36**: 181–186, 301-306, 375–381, 1908; **37**: 68–72, 103–109, 157–160, 193–199, 248–252, 1909. This was reprinted, repaged, in pamphlet form, Washington, 1909. Reference may be made to this bibliography for papers on evaporation antedating 1908.

hastened that from the porcelain cylinder." This is no doubt correct to a considerable extent, though temperature and humidity changes may also have had an influence. Nevertheless, in spite of the clear evidence that the ratio of hourly loss from cup to hourly loss from pan actually fluctuated as much as from 84.7 to 114.4, an average of all the hourly ratios was taken as showing the relation of the two rates for the entire day. Such a mean value does, of course, represent the period for which it was obtained, but the night hours were not included in that study. If the different days of the general period were nearly similar, and if the average ratio employed had been derived by use of night as well as day rates, then the reductions of cup readings to units of depth (given on p. 29 of the same publication) should be approximately correct. As it is, these reductions are at least highly questionable excepting in a merely approximate way.

The mistake just mentioned befogged the writer's appreciation of the general atmometric problem for several years, and the real condition of affairs in this connection came to consciousness but slowly. In the summer of 1909 the method of standardizing porous cups was altered so as to make use of a water surface as a basis. At this time it was clearly appreciated that the kind of pan used must be highly important, but the possible difference between the effects of a given change in the surroundings, upon the rates of loss from cup and pan, was quite lost sight of—notwithstanding the suggestion of this difference already made in 1906. Accordingly, the fullest account of the porous cup atmometer so far published (the writer's paper of 1910, already cited) gives an erroneous method of reduction of evaporation rates from this instrument to units of depth from free water. The experimentation upon which this procedure was based lasted for several summer months, and showed satisfactory agreement between the reduction coefficients from day to day, no doubt because no very great climatic changes were then encountered and the effective conditions for each day of the series were much like those for any other.

During the following summer, however, a period of extraordinarily hot weather brought the coefficient of the standard cup (of earlier work) to a value much lower than that exhibited in 1909, and suggested the carrying out of a series of experiments bearing upon the effect of temperature upon the value of this coefficient of the standard cup, as compared to the standard pan then employed. These tests clearly showed that, as the temperature rises, the coefficient of the standard cup, referred to the standard pan, decreases, and it proved to be possible, by manipulating the temperature, to give this coefficient almost any desired value, within a broad range. It thus became clear that a rise in temperature produces a relatively greater increase in evaporation from the cup than from the pan. It may be suggested that the higher the temperature of the air the more pronounced should be the convection currents about the cup, while the corresponding alteration in convection currents over the free water surface is probably but slight, owing to the horizontal position of the latter. These comparisons of cups and pans were carried out, as far as possible, without breeze, so that the effect of differences in air convection should have been pronounced.

Whatever may be the physical explanation of the findings of these experiments, they made it very obvious that it is impossible to reduce the rate of loss from a porous cup to units of depth from a water surface, and this put an end to cup standardization with the pan as a basis. The coefficients of the cups of 1908 were therefore recalculated, to the older basis of standard cups, and the fact of this return to the original method was stated in a later paper.[4] The reasons for this change have never been presented until now.

This whole matter of the influence of the atmometer itself upon the evaporation rate per unit of evaporating surface is quite clear from the fundamental principle that the rate of water loss depends upon the conditions of the entire surroundings, not merely upon the evaporating power of the air. The special conditions due to the nature of the instrument accompany the instrument from place to place and affect the evaporation rate by variously modifying the influence of the surrounding conditions at each locality. In other terms, the *exposure of the evaporating surface to the remainder of the instrument* forms an important and usually not negligible part of the general exposure. Thus, to say that atmospheric evaporating powers are to be comparably measured only by giving the evaporating surfaces similar exposures, implies that the entire nature of every instrument should be as nearly alike as possible; what may be called the *internal* or *instrumental* exposure of the active surfaces must be the same if the external conditions are to register comparable effects. The mutual influences of the various conditions within and without the instrument, and the summed influence exerted by all these conditions acting together, are far too complex to admit of correction being applied to bring the readings from different kinds of atmometers into a comparable state. Such corrections may become possible in time, through refined physical studies, but numerous attempts simply to deduce the evaporation rate of one kind of instrument from various measured conditions of the surroundings have not furnished results that are at all encouraging in this direction. The literature contains many experimentally derived formulas for this sort of reduction, but none seem to have obtained a completeness or precision adequate to render them available excepting for the roughest sort of approximations.

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[4] Livingston, B. E., A rotating table for standardizing porous cup atmometers. Plant World **15**: 157–162, 1912.

Summarizing the points thus far brought out, hazarding a repetition for the sake of emphasis, the evaporating power of the air—that is, its power to remove water vapor from a surface of liquid or solid water—can never be directly measured only with reference to some standard evaporating surface. For the preparation of duplicate evaporating surfaces it is necessary, not only that the areas of these be the same, but that their *forms* or shapes be also the same. Furthermore, all of the immediate surroundings of these water surfaces excepting the conditions of the air, the effectiveness of which are to be studied—must also be alike. The surroundings include the magnitude and form of the water mass behind the exposed surface, the sort of container which holds the water mass in place, etc. In brief, if the evaporating power of the air is to be measured at different places, or for different time periods at the same place, it is quite essential that the several atmometers employed shall be as nearly alike, in all particulars, as is possible. Of course it is physically impossible to construct several instruments exactly alike, and the slight differences which occur should always be cared for by calibration, as in the case of anemometers, thermometers and the like. Any alteration of the instruments that may occur during the period of operation should also be cared for by recalibrations carried out from time to time. It is positively essential that some single form of instrument be adopted throughout each series of comparative measurements, and it is quite impracticable—excepting in a roughly approximate way—to derive coefficients by which readings from one form of instrument may be made comparable with those from another form.

### *Units of Measurement*

Connected with a discussion of atmometry in general, should go some consideration of the kind of units to be used in comparative studies of evaporation rates. The misapprehension mentioned above, that free water somehow furnishes the true standard evaporating surface for such studies, is usually accompanied by another misapprehension, that units of depth are somehow the truly fundamental units, in terms of which the evaporating power of the air should always be measured. This proposition is probably to be related to a desire, on the part of meteorologists and climatologists, to compare rainfall with evaporation.

Rainfall is measured in depth units and its measurement is not attended with serious difficulties; the size, shape and material of the gauges exert relatively but negligible influence upon the readings, and the variations in exposure commonly allowed are not great enough to be considerable. Hence it may have *seemed* to follow, that evaporation (which is obviously a sort of *negative* rainfall) should be measurable in the same kind of units. As has been indicated, however, many conditions influence the rate of loss from an atmometer that do not seriously affect the readings of a rain gauge. To illustrate, a small pan of water loses relatively (per unit of surface) more by evaporation than does a large pan, while the size of rain gauge funnels is without appreciable effect upon the amount of water taken in, per unit of funnel area. It may be remarked, also, that the very presence and operation of an evaporating surface decreases the evaporating power of the air in its vicinity, while the receiving or absorbing action of the rain funnel is quite without influence towards decreasing rainfall. This is an important consideration for those who regard units of depth of evaporation and precipitation as comparable units. The proposition is much more complicated than here indicated, but limited space precludes a more thorough analysis.

Since it is aimed simply to measure the amount of water lost from a specified standard evaporating surface, it is clear that the only rational units thus to be employed are those of weight, or mass. Volume units are as satisfactory as those of weight only when the relatively small variation in specific gravity caused by changing temperature may be neglected; which may be safely done in practically all cases where atmometric measurements are employed. The investigator should be conscious of such neglect, however. Units of depth cannot be conveniently employed excepting with free water surfaces; other forms of atmometer lend themselves more readily to the employment of weight or volume units. In the case of pans or tanks of water, depth units (which are to be avoided, in any event, because of the widespread but mistaken idea that these are directly comparable to similar units of precipitation) may of course be transformed into weight or volume units when the necessary coefficient is given but always for some specific size, shape, etc., of pan.

Of course the most essential principle in this regard is that the same units must be used for all the instruments the readings of which are to be compared.

(*To be continued.*)

# NATURAL REFORESTATION IN THE MOUNTAINS OF NORTHERN IDAHO

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The factors affecting the natural reforestation of a fire-denuded area may, in general, be said to be the same in Idaho and Oregon as in Maine or Minnesota. There may be and actually are differences in detail as to what species of herbaceous and shrubby plants may prepare the way for the more delicate seedlings of those trees native to the particular locality. But the principle prevails everywhere that certain plants or plant societies are antecedent and probably essential to the appearance and permanent establishment of a forest. The first step in the reforestation of a fire-swept area is the restoration of the conditions necessary to insure the germination and vigorous early development of the tree seedlings. The presence of humus in the soil insures a certain degree of moisture conservation and the retention of certain ingredients of plant food so easily lost by drainage.

Experience and observation teach us that however hardy, however well equipped, may be such trees as those which come to occupy the most trying situations, they were doubtless so sensitive to environmental factors during their first years as to have perished but for the fact that there must have prevailed a proper and essential balance of physiologic factors. To establish this balance may have required but a year, or it may have taken a much longer time.

In this paper it is not our purpose to discourse on the laws which regulate natural reforestation in different sections of the continent; notwithstanding the fact that great practical benefit would very likely result from an extended and careful scientific study of the factors which determine such growth.

Ordinarily the denudation of any considerable area of coniferous forest land means an end of that chapter of forest history. Witness, for example, the thousands of acres of "pine barrens" in Minnesota, Michigan, and Ontario where but a few decades ago stood splendid mixed forests of white and Norway pine, and spruce and fir, holding their own against time and the elements. It is because man in his exploitation of these forests imposed upon their territory an absence of certain growth factors vital to natural reforestation that it has since been impossible for these coniferous species to reëstablish themselves. Time has shown that protection from destructive ground fires will in many instances promote natural reforestation. Zavitz,[1] who has made an extensive and careful study of forest conditions in Ontario, states that the reforestation of the denuded land areas is a problem involving fire control rather than one calling for the hand-planting of pines. In Sincoe County, for example, a certain district comprising approximately 50,000 acres, and at one time covered with valuable red pine, still supports enough old seed-bearing red and white pines to insure reforestation were it not for the fact that destructive ground fires are allowed to run.

That the production of a coniferous forest depends greatly upon a real balance of physiological factors can not be denied. No matter how favorable may be the moisture supply, an excessive rate of evaporation will inhibit or make impossible the growth of a crop of seedlings for as long as a single season. Then, again, extreme exposure to sunlight may prove destructive. Or, two or more factors in excess or deficiency may prevent altogether the growth of young plants.

The following example is illustrative. On Kamiak Mountain, an isolated butte near Viola, Idaho, evaporation stations were maintained during the summer of 1913. One Livingston's porous cup atmometer was operated on a south slope a few meters from the top of the ridge, and a second atmometer was placed just over the ridge on the north slope. Neither station was occupied by mature trees, although Douglas fir and yellow pine grew on the ridge and north slope on both sides of the prairie in which data were obtained. Coniferous seeds were available at both stations and pine cones were actually lying scattered about on the ground. On the sheltered slope a few pine and fir seedlings had established themsleves, while none occurred near the station on the south slope. The average daily evaporation in the area occupied by these small seedlings, from May 10 to September 5 was 19 cc., while the exposed side of the ridge gave an average daily evaporation of 27.7 cc. The greatest stress on the south side for any seven-day period occurred during the week ending August 29, when the average daily evaporation reached 50.8 cc. On the north side during the same interval it averaged only 34 cc. per day.

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[1] Zavitz, E. J., Report on the Reforestation of Waste Lands in Southern Ontario, 10, 1908.

Figure 1 shows a sharp ecotone between prairie and forest. This spur of Tekoa Mountain is illustrative of many similar situations of transition from grassland to forest. The sheltered northeast slope supports a dense growth of yellow pine, Douglas fir, and some tamarack, but these invade the prairie of the windward slope with great difficulty. Figure 2 shows a similar situation and illustrates the effect of exposure to wind upon the few trees that have succeeded in growing upon the ridge.

Likewise the destruction by fire of the accumulated humus constituting that all-important part of the forest floor may retard for many years the reappearance of young trees of sufficient vigor to endure.

A study of the physiology of reforestation without taking into account the intimate relation of other plants to the reappearance and permanent establishment of the forest growth would be incomplete; for there can be no doubt concerning the vital importance of these plants as agents modifying the factors influencing the restoration of that physiological balance so essential to the incipient growth of coniferous seedlings.

The Thatuna Hills, a western spur of the Bitter Root Moun-

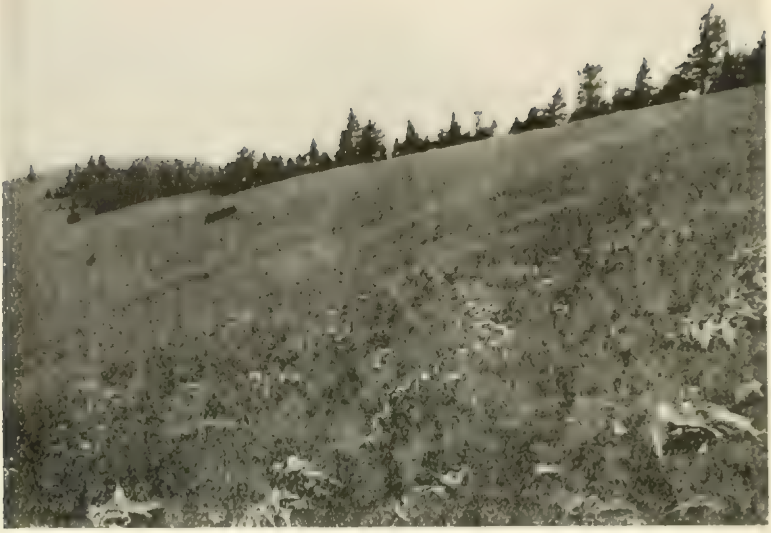

Fig. 1. A sharp ecotone between prairie and forest. The sheltered northeast slope is clothed with a dense forest of yellow pine, Douglas fir and some tamarack. Tekoa Mountain, Washington.

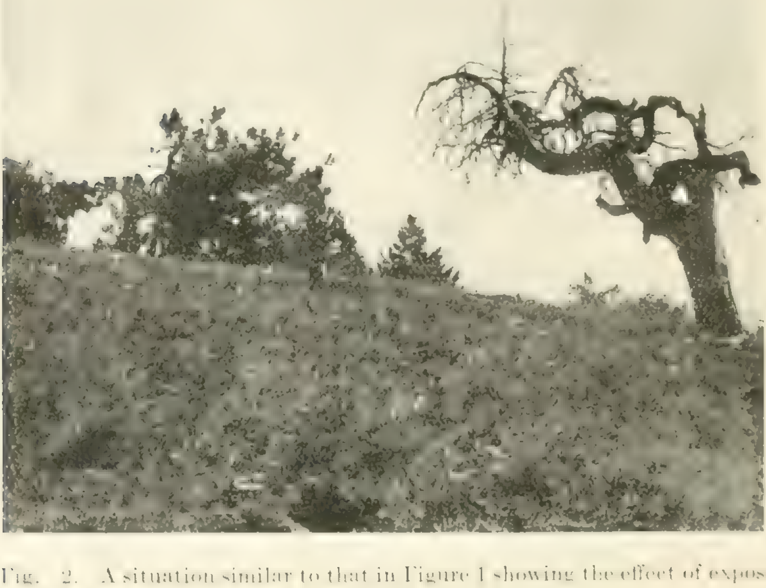

Fig. 2. A situation similar to that in Figure 1 showing the effect of exposure to wind upon the yellow pine

tains and located in northern Idaho, support a rich coniferous flora consisting of the Western larch, *Larix occidentalis*, the white fir, *Abies grandis*, the Douglas fir, *Pseudotsuga mucronata*, Englemann spruce, *Picea engelmanni*, yellow pine, *Pinus ponderosa*, white pine, *Pinus monticola*, lodge pole pine, *Pinus contorta* var. *murrayana*, white cedar, *Thuya plicata* and the Western yew, *Taxus brevifolia*. These hills, rising to a maximum elevation of 4950 feet above sea level, offer an unusual variety of slope exposure, cañons, and moisture supply. The western and southwestern slopes of these hills receive at all times the full brunt of the prevailing winds which sweep across the many miles of open prairie and desert of south central Washington and northern Oregon and not infrequently attain a velocity of 50 miles an hour. These wind-swept slopes are clothed with a fairly dense growth of Douglas fir, tamarack, and yellow pine except in sheltered ravines where one may find the white cedar, the white fir and an occasional spruce. Pure forests of yellow pine are not unusual, but mixed forests of pine and Douglas fir, or of tamarack, white fir and cedar are more abundant, and it is interesting to note that where reforestation has occurred, slopes formerly occupied by any one of these forest types have in most instances been reclothed with the same species.

Figure 3 shows a north slope which was cut over more than 25 years ago, while in figure 4 the steep southern exposure just opposite is shown. A belt transect 2 meters wide from near the top of the north slope to its foot showed this forest to be composed of 30% tamarack, 26% white fir, 39.5% cedar, 4% red fir, and 0.5% yellow pine. The exposed opposite slope was studied in a similar manner and revealed a decidedly different composition with 10% tamarack, 40% white fir, 14% red fir, and 36% yellow pine. Superficially the north slope appears to be clothed with a nearly pure tamarack forest, due to the more rapid vertical growth of this species. The cedars are mostly small; in fact many are mere seedlings. An actual count of the annual rings showed that they came in after the other trees had by their shade made conditions less xerophytic. Such mixed forests of tamarack, white fir and cedar are very characteristic of the sheltered slopes and ravines (fig. 5). The large percentage of white fir shown to occur on the south slope occupies dense thickets near the protected base. That the south slope supports a very open forest (mostly yellow pine and Douglas fir above the ravine) is shown by the fact that the average number of trees per square meter is only one, as compared with 3.5 per unit area on the north slope.

No less characteristic of the two exposures are the shrubs of the undergrowth. *Opulaster pauciflorus*, *Ceanothus velutinus* and *Salix scouleriana* make up the chief shrubby growth on the south slope, often covering many square meters exclusively. On the north slope both *Opulaster pauciflorus* and *Ceanothus velutinus* occur but rarely, while *Vaccinium membranaceum* is more abundant than *Salix scouleriana*. *Coptis occidentalis*, *Clintonia uniflora*, *Thalictrum occidentale*, *Mitella stauropetala*, *Galium* sp., *Asarum caudatum*, *Anemone piperi*, *Pyrola bracteata*, *Cytherea*

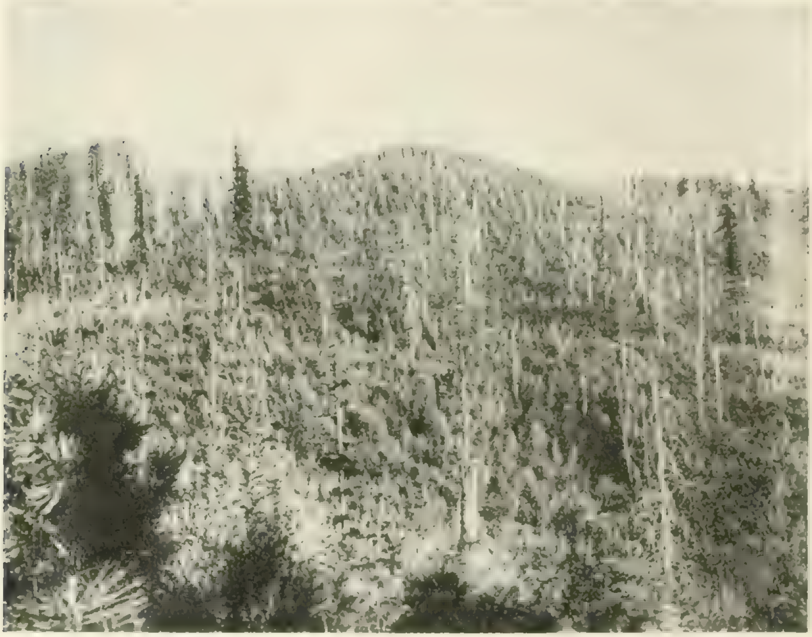

Fig. 3. A young forest of white fir, tamarack, and cedar occupying a cut-over north slope in Thatuna Hills.

*bulbosa* and species of *Smilicina*, all found here, are typical plants of the more moist slopes and contrast markedly with *Calamagrostis suksdorfii*, *Bromus marginatus*, *Pteridium aquilinum* var. *pubescens*, *Penstemon pinetorum*, *Phaca mortoni*, *Aster*

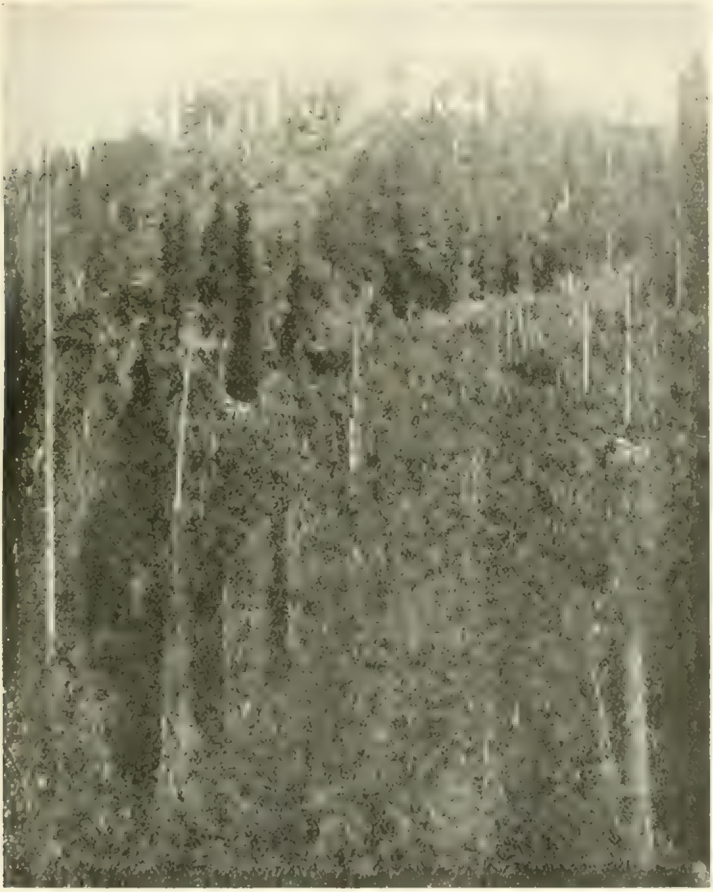

Fig. 4. The steep south exposure just opposite that shown in Figure 3, clothed with an open forest of yellow pine, red fir, and tamarack.

*conspicuus*, *Anaphalis margaritacea* var. *occidentalis*, *Antennaria racemosa*, *Pedicularis racemosa*, and *Berberis repens*, found on the more open south mountain side.

About 26 years ago many square miles of these hills were overrun by a fire which destroyed more or less completely much of the virgin timber, leaving here and there a few living trees representing the different species to serve as seed trees in subsequent years. These burns covered chiefly the north and northeast slopes of the mountains. In these mixed forests of white

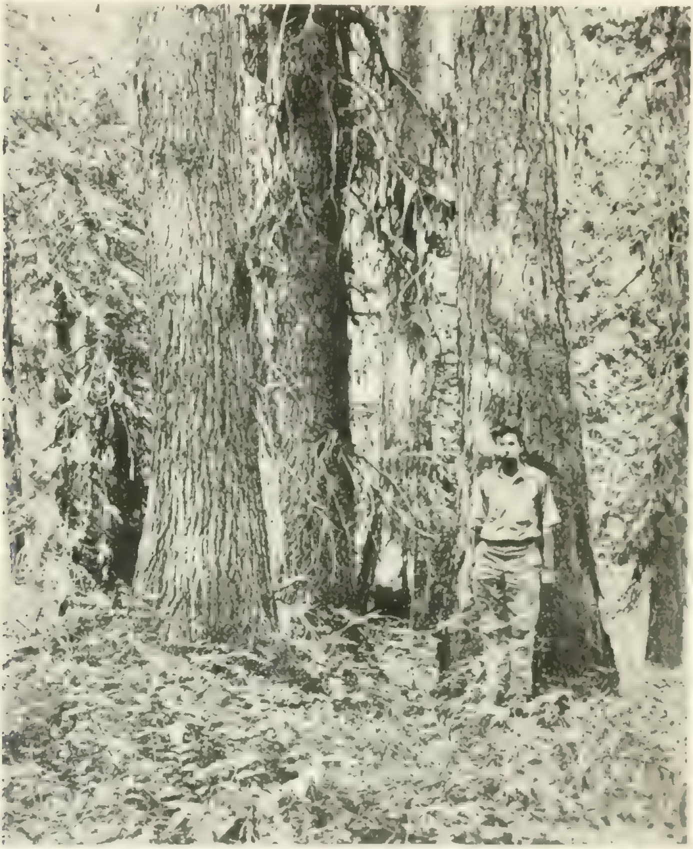

Fig. 5. A virgin forest of white fir, tamarack and cedar. Characteristic plants are *Acer glabrum* var. *douglasii*, *Lonicera utahensis*, *Vaccinium membranaceum*, *Ribes lacustre*, *Thalictrum occidentale*, and *Disporum* spp., under which is a carpet of *Smilacina sessilifolia*, *Coptis occidentalis*, *Asarum caudatum*, and *Clintonia uniflora*. Thatuna Hills, Idaho.

fir, tamarack, Douglas fir and cedar, the thick-barked tamarack suffered least and often only the trees of this species less than 6 to 8 inches in diameter were killed. This gave rise to what are apparently nearly pure forests of tamarack; but in most all cases sufficient seed trees of the other species were left to insure re-seeding; and at present a new generation of white fir and tamarack are especially prominent (fig. 6). In some of the more accessible cañons, lumbering has been carried on and in some places the operations of the lumberman have been followed by ground fires, some of which must have occurred not more than 5 years prior to the time when the authors made their observations.

On these most recent burns the predominating plants were *Epilobium angustifolium*, and *Carduus breweri* and occasional specimens of *Erigeron acris*. These three species along with other annuals and biennials and some young willows afforded conditions suitable to the early growth of the scattered seedlings of *Larix*, *Pseudotsuga* and *Pinus ponderosa*, which had already established themselves. On those slopes formerly occupied by a mixed forest of larch, Douglas fir, white fir, spruce, and white cedar, it was interesting to note that in the older burns these same species had succeeded in reëstablishing themselves. Cutting off a large number of the trees of each species at the surface of the ground and counting the annual rings, it was found that the most xerophytic species, *i.e.*, Douglas fir, yellow pine, and larch, were the oldest, and therefore, the first to establish themselves. It is also a matter of interest to note that a period of 2 or more years must elapse before any but a limited number of even the hardiest of these trees can launch into permanency. Naturally, those slopes and situations affording the greatest degree of protection from evaporation and excessive heat and light produce a more abundant stand of those annuals and biennials which prepare the way for the coniferous forest of later years. And observation has shown that the preparation of exposed slopes for coniferous seedlings is considerably delayed because of the limited number of individual herbaceous plants produced in any season and the consequent slow accumulation of humus.

During the month of August, 1910, the greater part of northern Idaho and much of eastern Montana were swept by one of the most extensive and destructive forest fires ever experienced in that part of the country. In many heavily wooded cañons the draft was so violent during the fire and the heat so intense as to destroy every vestige of life above ground (fig. 7).

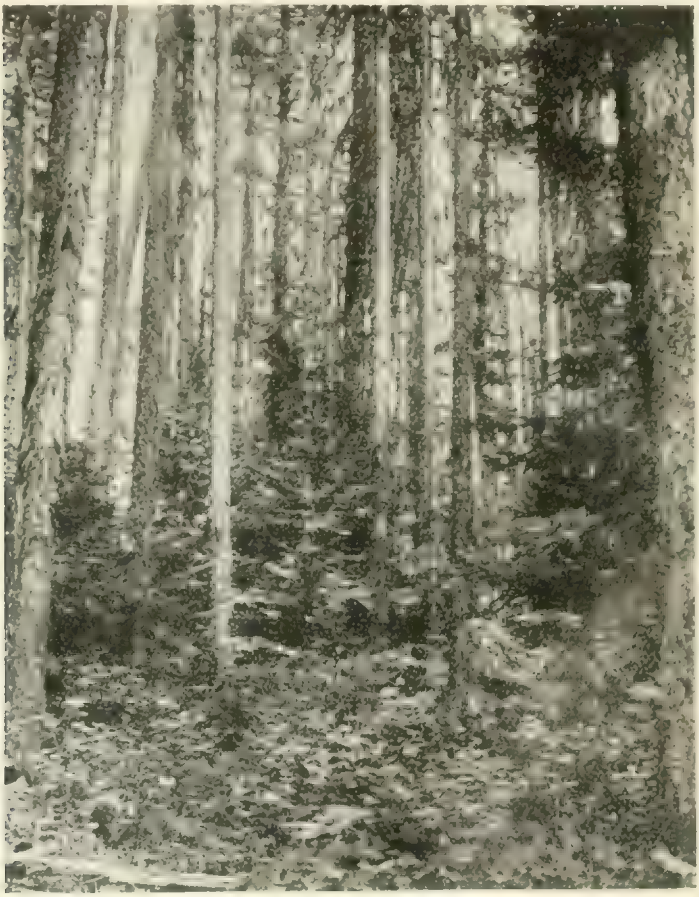

Fig. 6. Interior view of a forest burned over about 26 years ago. The older trees are mostly tamarack under which the white fir is especially abundant.

The town of St. Maries, Idaho, lies against the slopes of foothills which, prior to 1910, were covered with a more or less mixed forest of coniferous trees comprising the following species: *Pseudotsuga mucronata*, in practically all situations; *Pinus ponderosa*, abundant on south slopes and in exposed and rocky situations; *Larix occidentalis* associated with *Abies grandis* and *Pseudotsuga; Pinus monticola* and *Thuya plicata* accompanied by individuals of *Pseudotsuga* and *Abies*, confined generally to the cañons and rich levels at the bases of north slopes.

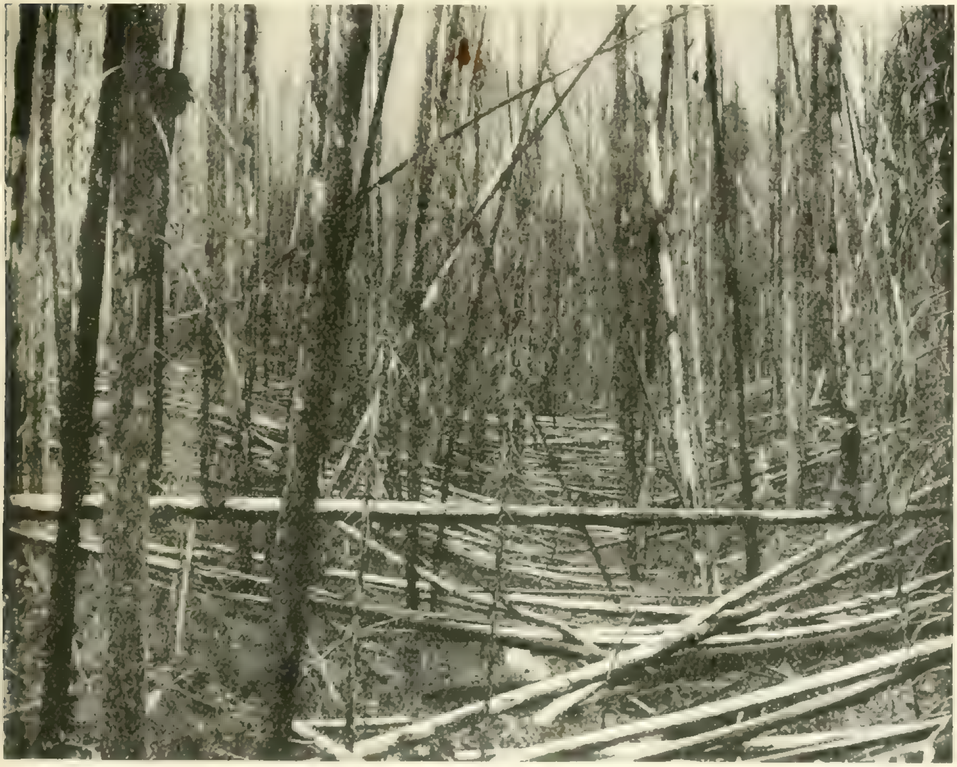

Fig. 7. An old "burn" in Ferry County, Washington. Typical representation of the destruction by fire of the coniferous forests of the Northwest.

These mountain slopes were overrun by fire on August 21 and 22, 1910. Seeming to represent fairly the average forest conditions for northern Idaho, it was decided that here if anywhere would be the most satisfactory place to carry on a study of the problem of natural reforestation. The region was not visited during the summer of 1911, hence a complete account of the plant successions and list of species can not be furnished. But observations made on east, north and northwest slopes on May 25, 1912, established the fact that in all probability *Funaria hygrometrica* and *Marchantia polymorpha* were among the very first of the pioneers to help reclaim the unshaded and charred soil. It was also possible to identify the following angiosperms of the preceding year's growth: *Carduus breweri*, *Erigeron* sp., *Epilobium angustifolium*, *Arnica cordifolia*, *Salix* sp., *Physocarpus pauciflorus*, and *Erythronium grandiflorum*. It is not unlikely that other more perishable species were present, but identifiable remains were quite wanting.

Plants observed on May 25, 1912, and belonging to the 1912 growth were the following: predominant everywhere, *Epilobium angustifolium*, individuals of which varied in size from that of mere seedlings to plants 12 to 18 inches in height. These (fire weeds) often occur as abundantly as 34 individuals per square meter, and certainly do much toward reducing light intensities and evaporation. Thousands of the smallest of these were succumbing to an epidemic of *Aecidium*. Other herbaceous plants observed were *Carduus breweri*, everywhere abundant; and here, as observed elsewhere, one of the first seed plants to secure a footing in forest burns. Associated with *Epilobium* and *Carduus* were *Erigeron acris*, *Arnica cordifolia*, *Antennaria luzuloides*, and *Salix scouleriana*. These species all depend upon wind for seed distribution; and doubtless this accounts in some measure for the fact that they are among the very first seed plants to take possession of fire devastated areas.

Every inch of ground seemed to be occupied by *Funaria*, a plant of very considerable importance to the complete development of other forms, because of the double rôle it plays in the conservation of soil moisture and the formation of humus.

Other plants were *Physocarpus pauciflorus*, *Rosa gymnocarpa*, *Potentilla* sp., *Mitella stauropetala* (abundant), *Leptotaenia mul-*

*tifida, Rubus nutkanus, Disporum trachycarpum, Arenaria macrophylla, Antennaria luzuloides, Coptis occidentalis, Viola canina,* two species of *Lathyrus, Vicia* sp., *Zygadenus venenosus, Fritillaria lanceolata,* and *Erythronium grandiflorum.* The three last named plants occurred in considerable abundance and upon investigation it was found that their bulbs were, in every case examined, at depths of 5 to 7 inches below the soil surface. These bulbous plants could have been hardly so abundant had they depended upon winds or other natural carrying agents for the distribution of their seed. It is also quite probable that many if not all the shrubs in which an underground root-stock development obtains were able to withstand the effects of the fire. In fact, one can with difficulty account for the abundance and general distribution of such plants in any other way, for their growth habits, are such as to preclude the possibility of so much development in a single season from seed. It is of interest here to note that in spite of the terrific heat which must have prevailed over those mountain slopes, except where the undergrowth was dense, a considerable depth of humus remained intact. Where this was wholly consumed and the soil had been washed bare by rains there was a fairly complete turf of *Funaria* and *Marchantia* along with certain herbaceous plants already given. The effects of this forest fire were more profound in certain parts of the forest than in others, depending somewhat upon the topography of the devastated region. In the "draws" or small lateral cañons where growth conditions were such as to produce the most excellent stand of white pine (*Pinus monticola*), Douglas fir, white fir and cedar, the fire was most destructive, leaving no trees alive. Whereas, on lateral or secondary ridges it was frequently observed that from 25% to 75% of these species, including yellow pine, survived the heat. These constituted the seed trees so valuable in the reforestation now going forward.

A diligent search was made for any seedlings of the cone-bearing trees characteristic of the region under observation, and a few were found. A limited number of these (all were *Larix occidentalis*) were from seed germinated in 1911, but the majority were but a few weeks old at the time of observation. They were indeed scarce; not more than sixty to eighty per acre on east and north slopes and none at all on south and southeast or southwest exposures. In two instances it was observed that as many as fifteen to twenty seedlings were growing in one spot as though a cone had become planted and all its viable seeds had germinated. The area investigated seemed to show no signs of any other conifer, which fact corroborates observations of a similar nature made 2 years earlier in a certain denuded section in the Thatuna Hills.

In September, 1912, another trip was taken to the hills about St. Maries, and it was found that between May 25 and the September date many seedlings of *Thuya*, *Larix*, *Pseudotsuga* and a few of *Abies* had sprung into existence, apparently from seed of scattered surviving parent trees in the immediate neighborhood. Their distribution was very irregular. In some areas of a square meter or more none could be found, while in other more favored spots the seedlings would average as many as eight per square meter. The ground occupied by these seedlings was well covered with a mulch of the dead leaves and stems of such herbaceous plants as have already been described for the region.

An examination of denuded south slopes where the original forest growth consisted of an abundant stand of *Pinus ponderosa* with scattered individuals of *Pseudotsuga mucronata* resulted in the enumeration of the following plants: *Funaria hygrometrica*, *Achillea* sp., *Symphoricarpos racemosus*, *Pteridium aquilinum* var. *pubescens* (most abundant), *Epilobium paniculatum*, *Carduus breweri*, all, excepting *Pteridium*, about equally abundant and intermingled so as to form a semi-shaded area. Stray specimens of *Aster douglasii*, *Rosa nutkana*, and *Gnaphalium* sp. were observed; and in spots *Berberis repens* was predominant.

The most careful search failed to reveal any coniferous seedlings even in the most favorably shaded ravines of these south slopes, an absence due, no doubt, to insufficient soil moisture and excessive evaporation, although the writers had no recording instruments in this field. That these same south mountain sides and their ravines and cañons will in the course of time be reclaimed by a new growth of yellow pine and Douglas fir can not be prevented so long as ground fires do not occur and natural growth conditions are not obliterated.

An example of the yellow pine, our hardiest tree pioneer, taking possession of an extremely xerophytic situation was carefully observed on Kamiak Mountain during the summer of 1913. Near the top of the mountain where the soil is rocky, *Pinus ponderosa* has succeeded in establishing itself on the exposed south slope. A weekly record was kept of the evaporating power of the air and of the moisture content of the soil near the edge of a group of pine trees under cover of which a few three- and four-year-old seedlings were growing. On May 10 a 25 cm. core of this quartzitic soil contained 21% of its dry weight (at 105° C.) of water. The soil moisture gradually decreased until on July 24 only 7.4% remained, and this was reduced to 4%

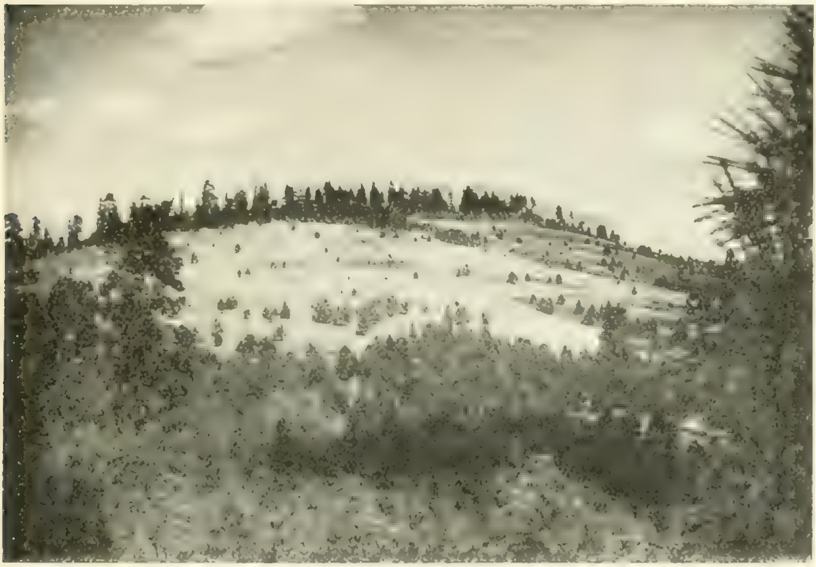

Fig. 8. A prairie on the exposed south slope of a quartzite butte near Viola, Idaho. It is being invaded by yellow pines which occupy the crest and the northwest side of the butte and the ravine in the foreground.

by September 5. The wilting coefficient of this soil free from rocks is 10%, and records show that after July 20 of 1913 no moisture was available in the first 25 cm. of soil. During the whole period from May 10 to September 5 the average daily evaporation was 24 cc. and during the week ending August 29 it ran as high as 44.8 cc. daily; and still the seedlings were not killed! In fact the soil mulch of needles and the shade afforded by the parent trees kept down the evaporation considerably both from soil and air, as compared with a prairie station a few meters lower down the mountain slope.

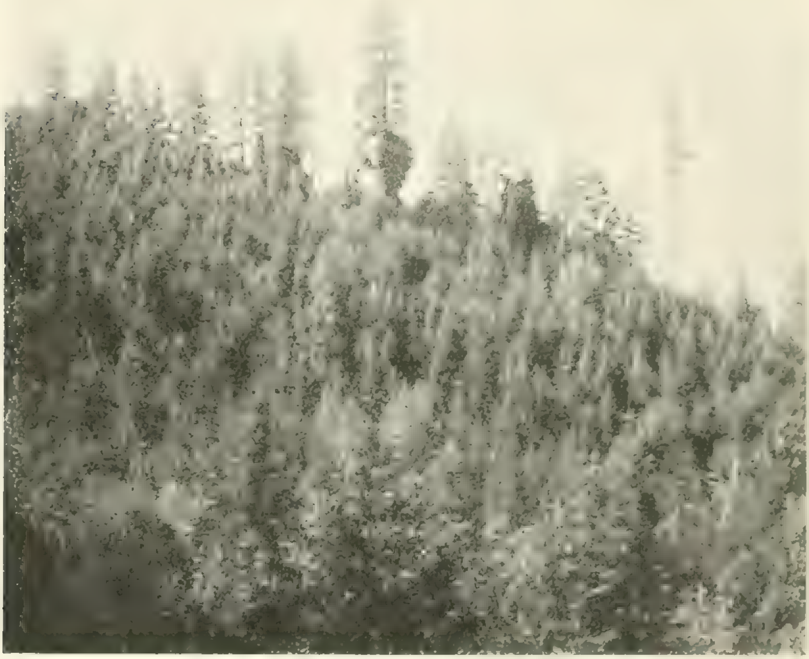

Fig. 9. The northeast side of the same butte shown in Figure 8. Douglas fir and tamarack are the chief components of this forest.

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[2] Weaver, John Ernst, Evaporation and Plant Succession in Southeastern Washington and Adjacent Idaho. The Plant World, **17**: 273-294, 1914.

This, we believe, is an extreme case, but it illustrates possibility of tree growth. The junior writer has shown[2] that although the yellow pine stage in succession is usually preceded by shrubs, especially *Opulaster pauciflorus*, *Prunus emarginata*, *Spiraea corymbosus*, or species of *Ceanothus*, it is still able to invade the prairie even without the protection of an intervening shrubby stage (figs. 8 and 9).

In a region such as the Pacific Northwest where summer rains are rare or altogether wanting, a new growth of coniferous trees depends upon soil moisture conservation. Soil moisture in sufficient amount to tide seedlings over a four months' period of drought and sunshine depends upon the presence of sufficient humus to retain the moisture and at the same time support a forest cover-growth of early maturing plants which will afford some protection to the tree seedlings of all but the most xerophytic species such as the yellow pine and Douglas fir. That the growth of herbaceous plants and shrubs may be so dense as to preclude the development of the young conifers not infrequently happens. That the preclusion of tree seedlings is usually due to light is a question to be determined by experiment and in the field. Repeated observations and measurements of the soil moisture content and the evaporating power of the air together with light values show conclusively that, although the soil moisture may be far more than sufficient for tree growth and the humidity of the air relatively high, yet when the light values drop to $\frac{1}{25}$ of normal sunshine our hardiest pioneer, the yellow pine, is excluded. These observed facts invite the inference that light is here the factor of prime importance. Of soil moisture and humus there may be plenty, but if light beyond a certain degree is shut out these seedlings will not be found.

# BOOKS AND CURRENT LITERATURE

A Manual of Weeds.—This delightfully written book[1] forms a part of the series of Rural Manuals edited by Dr. L. H. Bailey. The volume begins the subject by defining a weed as "a plant that is growing where it is desired that something else shall grow." The duration of life of the different kinds of weeds is discussed, also some general rules for preventing the growth of weeds, and the financial loss due to weeds. We are told that the loss to Minnesota alone from dockage because of weed seeds amounts to $2,000,000 annually.

Weeds may be useful because they enforce tillage. This discussion is followed by a brief account of the dissemination of weeds and chemical herbicides. Then follows the descriptive list of the weeds of the United States and Canada. The descriptions are all ample and most of the weeds are figured. These drawings are for the most part excellent. It would be difficult to recognize quack grass on p. 62, to distinguish *Setaria viridis* and *Setaria glauca*, 32 and 33. To these and a few others detail drawings of the spike and the floret would have aided in recognition.

A most useful feature of the book is the listing of all common names. Thus for Johnson grass there are given eight English names, for the common horsetail, six. The accepted common name is given in bold faced type followed by the botanical name. This is a most commendable feature. Time of bloom, seed time, range and habitat all precede the description. In some cases then, the author gives a little history on the introduction of the weed. When poisonous, something is said about its attack on animal and man. When the plant is useful for food or in medicine, the fact is mentioned. This is followed by means of control of the weed. The statements are very concise and will be most helpful to those who are interested in this important subject.

Some of the plants described are weeds only in a few places in Eastern North America. It is always difficult to draw a sharp line between a weed and a plant that is not injurious. A plant may be a weed in one place and not in another. *Epilobium spicatum* is a most troublesome weed in the northwest. It is, however, seldom seen in the southern Minnesota or in Iowa. Its range in the Manual is not correct, nor is the range correct for *Ranunculus acris.* This species is rare in Iowa, although common eastward and in the Lake Superior region. The figures of *Lepidium apetalum* and *Lepidium virginicum* should be transposed. Aside from a few such slips, the Manual is well prepared and is a worthy companion of other treatises on weeds, that have appeared in recent years. The make-up of the book is splendid. The volume should find a place in the public school library, where books of this kind are needed to supply information to those who are studying weeds, and it will also prove a most serviceable and valuable book to many college students.—L. H. PAMMEL.

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[1] Georgia, Ada E., A Manual of Weeds, with descriptions of all of the most troublesome plants in the United States and Canada, their habits of growth and distribution, with methods of control. Pp. 593, 385 illustrations by F. Schuyler Mathews. The Macmillan, Company New York. 1914.

FERNS OF WASHINGTON.—Frye and Jackson's little book, The Ferns of Washington,[4] is doing much to promote a more general knowledge of the ferns of that state. The edition is a limited one, only 500 copies having been printed. The writers find in the state, 30 species of Polypodiaceae, and 66 species of pteridophytes in all. The habitat and general range of each species is given, but not the range within the state.

The work has a key to families and keys to genera and species. These keys are admirable in that just as few technicalities as possible are introduced into them. The families, genera, and species are all described. The plates made from photographs and drawings aid greatly in the identification of species, and add much to interest in this attractive group of plants which form such a conspicuous feature of the vegetation in many portions of the state.—GEORGE B. RIGG.

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[4] Frye, T. C. and Jackson, Mabel M., The Ferns of Washington. Reprint from Am. Fern Jour. **3:** 65:83 and 97–108, 1913, and **4:** 6–14 and 41–57, 1914. Pp. 60, pl. 20. Lowman and Hanford, Seattle, 1914. ($0.40.)

# NOTES AND COMMENT

An Agricultural Atlas of the United States is being prepared by the Office of Farm Management in Washington, under the immediate direction of Mr. O. E. Baker. The Atlas will exhibit cartographically the latest statistics of crops, live stock, forest products, and farm property, and will show the distribution of areas under irrigation or dry farming. An entire section of the Atlas will be devoted to climate, and it has been carefully planned to exhibit just those aspects or intensities of climatic conditions which are of importance to vegetation and to crops. There will also be a section devoted to hypsometric, geological, soil and other physical maps. The completed Atlas will be of great usefulness in educational and research work, as well as for reference.

A tract of land near Greenfield, New York, has been given to the state for the purpose of preserving a large ledge of fossil algae situated upon it. A shelf of Cambrian limestone has been planed off by glacial ice so as to expose sections of *Cryptozoon*, a hemispherical calcareous marine alga. The tract will be named Lester Park, in honor of its donor, and it will be noteworthy as the first fossil botanical garden although it is by no means the first fossilized botanical garden.

# ATMOMETRY AND THE POROUS CUP ATMOMETER

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## II

## THE MAIN FORMS OF ATMOMETER

### *Choice as to Form of Instrument*

From what has been said in the last section the question arises: if the readings of one form of atmometer cannot be reduced, by mathematical treatment, to readings that might have been had from some other form of instrument (operating in the same place and at the same time), then by what criteria is the investigator to decide what sort of instrument to employ in a series of comparative measurements? Obviously, from the very nature of evaporation and from the medley of conditions by which it is influenced, the kind of evaporation to be studied must form the basis for this decision.

Where it is desired to approximate the rate of water loss from reservoirs and other large bodies of water, the floating pan is doubtless the most suitable instrument; it exposes a free water surface in much the same manner as does the reservoir itself. Where the study in hand involves the measurement of the evaporating power of the air as this affects plant transpiration, some form of saturated paper or porous clay surface is to be chosen; such surfaces may be exposed in a manner fairly comparable to the exposure of transpiring plant parts. To study evaporation from soils, a box or pan of moist soil seems more logical as an instrument than does a pan of water, though paper and porous clay surfaces may be adapted to this need. In short, the surface by means of which the evaporating power of the air is to be measured should possess as nearly the same form as possible and

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should be given the same kind of exposure as have the surfaces upon which the action of evaporating power is to be studied.

Aside from this general principle, however, there are various advantages and disadvantages connected with the use of each form of atmometer so far devised. A few considerations in this connection may find place here.

### *The Open Pan or Tank*

One of the main difficulties encountered in operating free water surfaces of considerable extent arises from the secondary wind effect. Increased wind velocity increases the evaporation rate, but at the same time increases the extent and alters the form of the free water surface, throwing it into ripples or waves. Thus the effect of rapid air movement cannot ever be studied with free liquid surfaces; the fluctuation of the condition to be studied causes marked alteration of *the instrument itself*. Furthermore, with high wind there is great danger of mechanical removal of water from the pan, by spray and splashing.

To prevent splashing it is essential to allow a portion of the lateral walls of the container to project above the water surface, and these projecting walls introduce variations in the effects produced by external changes. With a high wind the effect of the lateral protection may be negligible, with but slight air currents this effect is much more marked. In general, it is of course relatively more pronounced for small than large pans.

Another serious difficulty in tank operation arises from the fact that the depth of the water surface below the margin of the tank and the amount of water beneath the surface can be maintained only approximately constant, this usually by spasmodic additions. Here evaporation itself alters the nature of the exposed surface by changing the height of the projecting rim and the amount of water present. Also, the addition of water in times of rain is always a source of serious trouble, further complicated by the fact that raindrops frequently cause splashing and formation of spray.

Besides the addition of water by rain and its mechanical removal by rain impact and by wind action, there is frequently danger of removal of water by animals, especially small birds, which can rest on the edge of the tank while drinking. More than that, small animals, especially insects, fall into the water and often remain floating, thus seriously altering the surface. To avoid such disturbance wire screens must be introduced. These modify the wind action seriously and thus complicate the instrument, for all instruments with screens must have *similar* screens. It is scarcely practicable to screen tanks from small insects, the wind effect is so greatly modified by fine-meshed wire cloth.

In dealing with the evaporating power of the air as an environmental condition for organisms, the free water surface is practically useless beyond a rough approximation; it is next to impossible to give the evaporating surface any but a horizontal position (barring wave motion) and it cannot conveniently have any other form than that of a plane. Since it is essential, in such environmental studies, to give to the instrumental evaporating surface approximately the same exposure as that presented by the animal or plant surfaces to be dealt with, it is clear that only water-imbibing surfaces (*e.g.*, paper, porous clay) can thus be conveniently employed.

Finally, even fair accuracy of reading for short periods has never been possible with free surfaces; only small pans can be carefully weighed, the instrument must be protected from wind during the process of weighing, which occupies considerable time, and the errors thus introduced become relatively very large when periods of minutes or hours are employed.

### *The Piche Atmometer (Fig. 1)*

The Piche instrument,[5] having a disk of saturated blotting paper held horizontally against the lower (otherwise open) end of a graduated glass tube, which is closed above, possesses a number of advantages over the free water surface. The evaporating

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Piche, A., Note sur l'atmismomètre, instrument destinée à mesurer l'évaporation. Bull. Assoc. Sci. France **10**: 166–167, 1872. In this connection and in that of the Piche-Cantoni atmometer, see: Livingston, B. E., Paper atmometers for studies in evaporation. Plant World **14**: 281–289, 1911. Diagrams are there presented, and are reproduced in the present paper.

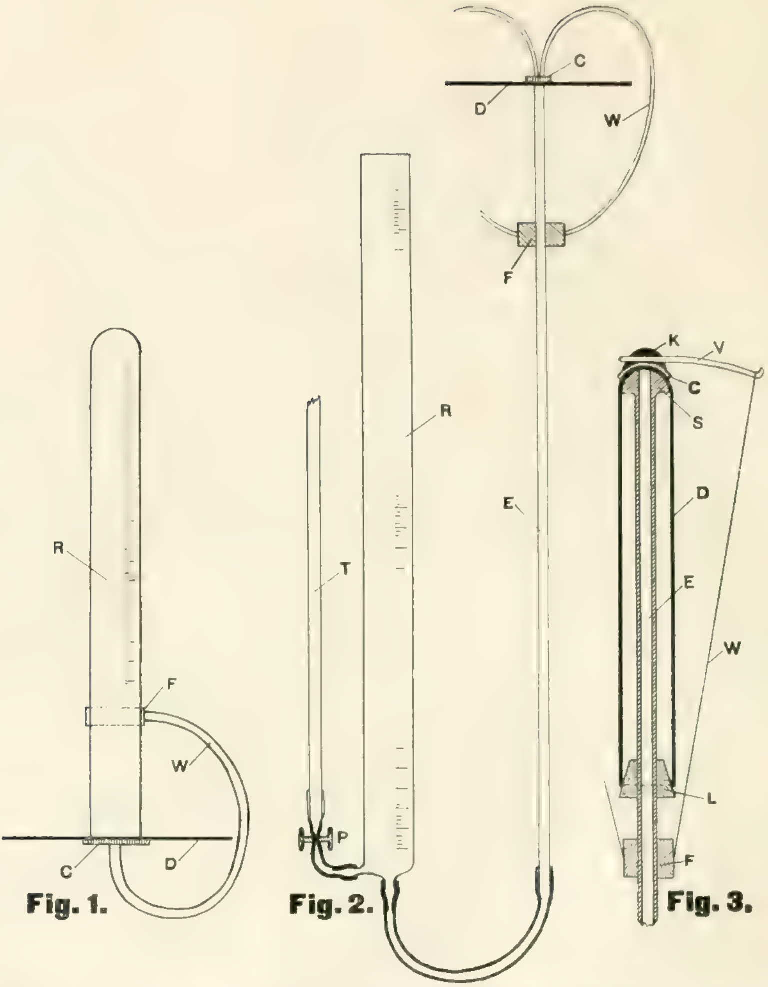

**Fig. 1.** **Fig. 2.** **Fig. 3.**

Fig. 1. Diagram showing essentials of the Piche atmometer. *R*, water reservoir; *D*, saturated paper disk, the latter supported against base of reservoir by metal disk (*C*). Spring (*W*) is attached by clip (*F*) to reservoir and applies pressure to *D*. (Reprinted from Plant World **14**: 286, 1911.)

Fig. 2. Diagram showing essentials of the Piche-Cantoni atmometer. *R*, burette reservoir for water, filled at will through tube (*T*) from higher supply, cut off by cock (*P*). *D*, absorbent paper disk, as in Piche instrument, held against the top of supply tube (*E*) by double spring (*W*) attached at *F* and applying pressure to plate (*C*). (Reprinted from Plant World **14**: 286, 1911.

Fig. 3. Diagram showing essentials of the Livingston paper cylinder atmometer, the rest of the instrument as in figure 2. *E*, tin supply tube; *D*, absorbent paper cylinder; *L*, cork supports holding lower edge of cylinder in place; *S*, tin seat, against which top of cylinder is appressed by glass cap (*C*). The latter is held in place by wire spring (*V*), cemented to *C* at *K* and flexed by fine wires (*W*), the latter attached to tube at *F*. (Reprinted from Plant World **14**: 286, 1911.)

surface is here that of imbibed water, held in place by the cohesion of the surface films themselves (surface tension) and by their adhesion to the supporting paper fibers. Distilled water is supplied to the disk from the tube and air enters at the center of the disk, through a very small opening in the paper, as water is withdrawn. Waves and splashing, considerable removal of water by animals, and serious obstruction of the surface by the bodies of the latter, are here not encountered. Also, the entire instrument may be readily weighed or it may be read in volume units.

The hydrostatic pressure upon the paper is rather irregularly variable, however; the entrance of air through the pin-hole is spasmodic, so that a considerable error is introduced into small readings. Also, the paper disk is apt to be deformed by strong wind, a feature comparable to that of ripples and waves on free water.

The horizontally placed disk, with its central obstruction to free wind action, while furnishing an exposure to atmospheric conditions much more suitable to biological needs than that offered by the open pan, nevertheless leaves much to be desired. Especially noteworthy is the fact that the Piche instrument must always operate as a unit; it is practically impossible to place the evaporating portion at a distance from the graduated reservoir, an arrangement often desirable in physiological studies.

Since all the water evaporated must pass longitudinally through the paper disk, from the central point of supply to the place of final vaporization, the size of the disk must be suited to the atmospheric evaporating power to be dealt with. In a region of low evaporation intensity the disk may be large, but must be smaller (to prevent the edges becoming dry at times) in an arid region.[6]

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[6] This phenomenon of dried disk edges has been described, in another connection, in the following: Livingston, B. E., and Brown, W. H., Relation of the daily march of transpiration to variations in the water content of foliage leaves. Bot. Gaz. **53**: 309–330, 1912. See page 313.

### *The Piche-Cantoni Atmometer (Fig. 2)*

This instrument[7] is a modification of that of Piche, the reservoir of water being here placed below and the paper disk above. Practically all the essential details of operation are the same as with the Piche, excepting that the spasmodic water movement (coincident with having the reservoir above) is here avoided, and that the evaporating surface may be placed at a considerable distance from the reservoir, in more satisfactory relation to plant foliage, etc. Distilled water should be used.

### *The Pickering Atmometer*

In the Pickering instrument[8] a rectangular piece of absorbent paper or cloth is held vertically by a suitable frame, and evaporation proceeds from both sides. Water is supplied by means of a tongue of the absorbent material reaching from the lower edge of the rectangle into a covered reservoir of distilled water below.

### *The Paper Cylinder (Fig. 3)*

The atmometer with paper cylinder[9] is a modification of the Piche-Cantoni form, with the paper disk replaced by a hollow cylinder of absorbent paper, closed at the upper end, where it is applied against the supply tube. Distilled water is employed. It has all the advantages of the Piche-Cantoni instrument and the additional one of exposing a cylindrical evaporating surface. Its main weakness as a cylindrical form lies in the fact that air leakage sometimes occurs at the junction of supply tube and paper cylinder, but a better form of mounting should obviate this difficulty. It is notable that the Livingston paper cylinders evaporate little or not at all from the interior surface, while the three paper forms above mentioned allow water loss from both surfaces.

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[7] Cantoni, G., Sulle condizioni di forma e di esposizione piu opportune per gli evaporimetri. Rend. R. Ist. Lomb. II. **12**: 941–946, 1879. See also the writer's article on paper atmometers cited above.

[8] Pickering, S. U., and Bedford, Duke of, A new form of evaporimeter. Woburn Exp. Fruit Farm Report **1897**: 168–174, 1897.

[9] Livingston, B. E., Paper atmometers for studies in evaporation and plant transpiration. Plant World **14**: 281–289, 1911.

### *The Bellani Porous Plate (Fig. 4)*

This kind of evaporating surface,[10] which appears never to have been taken seriously during nearly a century that has elapsed since Bellani described it, seems to possess a number of advantages over the free water surface. A horizontal porous clay disk closes the top of a vessel completely filled with distilled water, so that the lower surface of the disk is in contact with the liquid while the upper surface is exposed to the air. A small-bored, horizontal, graduated glass tube, open at its distal end, projects laterally from the vessel, and as evaporation takes place the air-water meniscus in this tube progresses toward the vessel, the tube being thus more or less slowly emptied of water. A suitable reservoir and controlling cock allows the meniscus to be pushed back over the scale, by admitting more water into the vessel. This is the earliest form of atmometer with an imbibed solid evaporating surface and the water reservoir at a lower level. The possibility of such an arrangement results from the fact that it requires considerable gas pressure to force a passage of gas through such a plate of porous pottery when saturated with water. Thus, atmospheric pressure is without influence upon the water mass in the vessel, excepting upon the index meniscus. As water evaporates from the porous surface more is imbibed from below and air pressure drives the meniscus inward along the scale, keeping the vessel filled and the plate continuously in contact with the water. It is to be noted that the Piche-Cantoni paper disk and the Livingston paper cylinder employ this same principle, only in those cases evaporation takes place from the marginal part of the paper projecting beyond the end of the supply tube. The Piche-Cantoni form is not unlike what we should have if we suppose Bellani's porous plate to extend laterally much beyond the vessel which it closes, at the same time supposing the diameter of this vessel to be decreased until it becomes a mere supply tube from the lower

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[10] Bellani, A., Descrizione di un nuovo atmidometro per servire di continuazione e fine alle reflessioni critiche intorno all' evaporazione. Gior. Fis. Chim. **3**$^{\mathrm{II}}$: 166–177, 1820. Also reprinted; Pavia, 1820.

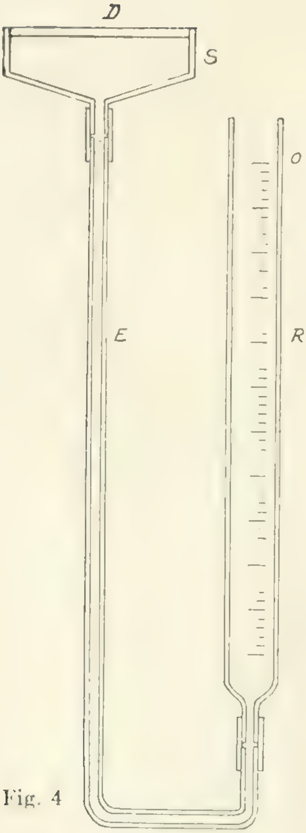

Fig. 4

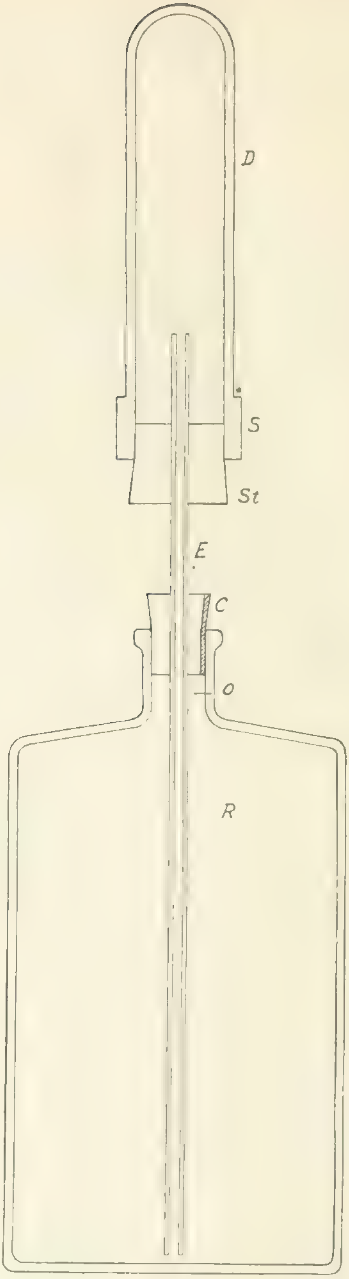

Fig. 5

Fig. 4. Diagram showing the essentials of the Bellani plate atmometer. *R*, burette reservoir for water; *D*, porous clay plate; *S*, metal support for *D*, connected to burette by supply tube (*E*).

Fig. 5. Diagram showing essentials of absorbing mounting of the porous cup atmometer. *R*, bottle reservoir for water; *D*, porous clay cup, with thickened rim (*S*), mounted by rubber stopper (*St*) on supply tube (*E*). *C*, cork stopper, with air opening at one side.

reservoir. It should be emphasized, however, that, whereas the paper forms above mentioned depend almost wholly upon lateral or longitudinal movement of water through the absorbent material, the Bellani plate transmits water perpendicularly to its surfaces, from one side to the other.

The Bellani surface is exposed like free water, horizontally, or may have any other position. It needs no projecting rim and of course waves and splashing cannot occur. At the same time, the relation of the exposed surface to the water mass below is not very different (especially as regards heat conditions) from the similar relation for an open pan. Furthermore, as has been seen, this arrangement allows very small readings to be made, by volume units, as for short periods of time or periods of low evaporation intensity.

This Bellani form of surface is worthy of the attention of those desiring a horizontal, plane evaporating surface, not altered by wind. It may be rendered non-absorbing, and thus freed from rain influence, by the use of the non-absorbing mounting to be described below. As here illustrated, it is conveniently mounted to take water from a burette reservoir. To the kind of alterations which may occur in saturated solid surfaces in general, and to ways of combatting such alterations, we shall turn presently.

### *The Porous Clay Cap Atmometer* (*Figs. 5-8*).

This instrument,[11] which has formed the basis for the extremely rapid development of atmometry among biologists, during the past eight or nine years, was independently devised three times before its possibilities became generally appreciated. Babinet's original short account, and Marié-Davy's[12] appreciative discussion, the latter appearing twenty years later than Babinet's, apparently attracted no serious attention. Forty-six years after Babinet's publication Mitscherlich[13] independently devised the instrument for agricultural experimentation, but even his publication seems not to have aroused biological workers. The present writer[14] again, also independently, devised the same instrument in the summer of 1904. Since that time, as has been remarked, the literature of atmometry has developed very rapidly in biological connections.

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[11] Babinet, J., Note sur un atmidscope. Compt. Rend. Paris **27**: 529-530, 1848.

[12] Marié-Davy, H., Atmidomètre à vase poreux de Babinet. Nouv. Mét. **2**: 253-254, 1869.

[13] Mitscherlich, A., Ein Verdunstungsmesser. Landw. Versuchsst. **60**: 63-72, 1904.

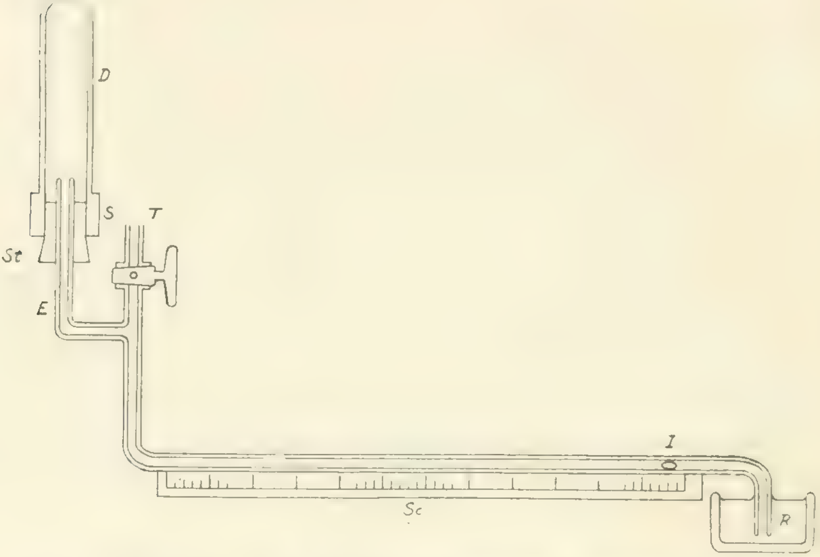

Fig. 6. Diagram showing essentials of potometer mounting of the porous cup atmometer. *R*, reservoir, from which water is drawn through tube (*E*); *I*, air-bubble index in *E*; *Sc*. graduated scale. *T*, tube from higher supply, from which water is admitted to drive index bubble back, controlled by cock. Porous cup (*D*) is mounted as in figure 5.

The porous cup surface may be derived, for the sake of a clear picture of relationships, from Bellani's porcelain plate. If we conceive this plate to be bent downward at its edges and extended until it forms a hollow porous clay cylinder, closed above and connected by a non-porous tube to a reservoir of distilled water at a lower level, we have the essentials of the porous cup. The cavity of the cup is filled with water, which is thus in direct con-

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[14] Livingston, *loc. cit.*, 1906.

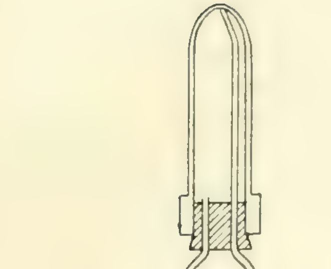

Fig. 7

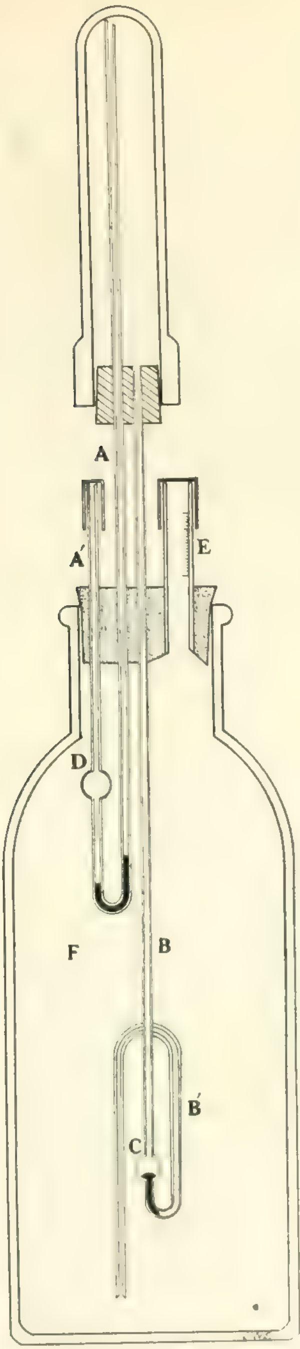

Fig. 8

Fig. 7. Diagram showing essentials of original form of non-absorbing mounting of the porous cup atmometer. *G*, reservoir; *E*, supply tube; *C*, *D*, mercury valves. Further description in text. (Reprinted from Plant World **13**: 79, 1910

**Fig. 8. Improved form of non-absoring porous cup atmometer devised by Shive.**

tact with the inner surface of the cup wall. The lower end of the cup is closed with a rubber stopper bearing glass or other suitable tubing connection to the reservoir. This tube is also full of water. The reservoir may be any suitable container; it is frequently a small mouth glass bottle with cork stopper and with a file mark on the neck to serve as zero point. In operation, this reservoir is filled to the file mark, the instrument is allowed to operate for a time period, and the reservoir is again filled, account being taken of the amount of water required, which is of course the amount lost by evaporation during the period. Where small readings are to be taken, the tube is often connected to the lower end of a burette which is filled from time to time, the decrease in the volume of water in the burette reservoir being read directly on the scale. In all cases the level of the water in the reservoir must be lower than the base of the porous surface.

It is obvious that the porous clay evaporating surface may have any desired form or size and that there is no danger of the drying of a part of the surface through excessive evaporation intensity, as is the case with the saturated paper surfaces mentioned above. It is also clear that, unlike the paper surfaces, the porous clay surface is in close proximity to a considerable mass of water, but the magnitude of this mass, in relation to the form and extent of the surface, may be modified to suit the requirements of the study in hand. With the porous cup form of instrument the evaporating surface may readily be placed at a considerable distance from the water reservoir.

The details of the operation of porous cups will receive attention farther on, after some important points regarding porous surfaces in general have been considered.

## THE POROUS EVAPORATING SURFACE IN GENERAL

### *Nature of the Porous Surface*

Besides paper and porous porcelain several other solid materials have been employed for evaporating surfaces. Woven fabric has sometimes been used. Perhaps the most frequent mention of porous surfaces in atmometry, however, refers to one of moist soil. Pans filled with moist soil, firmed to a smooth surface, have long been used by students of agricultural water relations. Regarding these, however, we need here make but the following observations. Some difficulty is usually experienced in preventing the soil surface becoming drier as evaporation proceeds, thus producing a profound change in the internal properties of the instrument. This trouble and some others are avoided by the employment of the Bellani arrangement of a horizontal, porous porcelain plate in contact with water below; porous porcelain is in many respects merely a layer of soil, so bound together that it will retain its shape. Thus, the general features of evaporation from such a plate should be in rather close agreement with those of water loss from a smoothly firmed soil surface.

Porous surfaces, whether of paper, porcelain or any other fixed material, all agree in presenting to the action of the air a water surface mechanically held in position (by surface tension, adhesion and the mechanical rigidity of the material employed) and hence, as has been mentioned, they are not thrown into waves by the wind, so that the danger of splashing which is always imminent with open vessels is completely obviated. Instruments employing such surfaces can be read in terms of either volume or weight and they can be readily arranged so as to give small readings and to expose the evaporating member at some distance from the reservoir. These are the main advantages of such forms of atmometers over those with a free water surface.

### *Two Classes of Porous Surfaces*

As has been seen we may consider two different arrangements of porous surface instruments. In one arrangement the saturated solid is in contact with unimbibed water for only a small portion of its extent; such forms are the Piche-Cantoni paper disk, the stretched paper or cloth of Pickering and the paper cylinder of the present writer. In the other arrangement the porous solid is backed by a mass of unimbibed water; of this form are the Bellani porcelain plate and the Babinet cup.

It is clearly possible, to decrease the amount of unimbibed water thus in general contact with the porous plate, per unit of surface, and thus to bring the two groups into closer similarity. The amount of this unimbibed water backing the solid, supporting material is a matter of considerable importance; for the temperature of the active surface,- an important feature in determining rate of water loss, must follow temperature changes in the surroundings less promptly (*i.e.*, with greater lag) the greater is the mass of water present behind the evaporating films. It was for this very consideration that the paper cylinder and its mounting were devised; it appeared clear that the porous clay cup, with its relatively thick, imbibed walls and its proportionally large amount of free water, should be less sensitive to external changes than such a water-holding device as the paper cylinder. For example, the temperature lag of the paper surface should be induced only by the small water mass actually held in the paper by imbibition or capillarity. In this respect such a surface should more nearly approach the form of exposure offered by ordinary thin leaves of plants. The porous clay cup should act in this regard more as do very succulent leaves, joints of cactus, etc., since here is a relatively large amount of water with relatively small surface.

This matter was made the subject of a special study, in which paper cylinders and porous cups were operated side by side, and simultaneously subjected to sudden and rather great changes in their surroundings, these changes being accomplished by moving the apparatus from one position to another, from sunshine to shade, from the open to a closed room, etc. From these tests it appeared that the lag exhibited by the cup is exceedingly slight, so slight as to be quite negligible unless readings are taken every minute or oftener. On this account it has not yet seemed necessary to develop the paper cylinder farther than has been done. Sooner or later this form of evaporating surface may assume importance, as problems become more refined.

### *Alteration of Porous Evaporating Surfaces by Operation*

All evaporating surfaces are apt to alter more or less with the progress of evaporation and with changes in the surroundings. As has been said, the secondary wind effect is completely removed in the case of non-flexible porous clay surfaces, while the removal of water by animals is practically serious only with free water. The accumulation of dust, etc., upon the saturated solid is perhaps more serious in its effects than the same sort of accumulation upon open water. Dust settling upon a pan of water decreases the rate of water loss, but usually (in its primary effect, at any rate) *increases* that rate from a paper or porous clay atmometer. Practically to remove this trouble, however, in case of porous porcelain, requires only that the surface be thoroughly cleaned occasionally. The papers, not being readily cleaned, should be replaced by new ones from time to time.

Besides the primary effect of the accumulation of dust upon saturated solid surfaces, a secondary and more serious one lies in the incrustation of the latter by soluble salts, which may be derived from dust. Such soluble salts, crystallizing out at points of most intense evaporation, sometimes decrease the rate of water loss and at other times appear to increase it. With paper, this trouble can be removed only by frequent replacement; with porcelain, cleansing of the exposed surface at short intervals usually obviates the difficulty. Passing pure water through the porous porcelain, in the direction of the usual movement of water, largely removes soluble material, beyond the limit of its adsorption.

It is absolutely essential, with all imbibed solids that only very good distilled water be employed, to avoid accumulation of salts as the water is evaporated. Impure water, especially with calcium salts, clogs the pores and eventually almost glazes the surface. This accumulation seems impossible of correction by frequent surface cleansing, as has been shown by actual tests. It can be removed, if not too pronounced, by forcing water or acid through the porcelain.

Whether a solid surface has altered with use is to be determined by standardization at frequent intervals, an operation, with which we shall have to deal in the detailed discussion of the porous cup, to be presented below.

### *Evaporation at Low Temperatures*

It is occasionally remarked that the porous cup atmometer is inadequate for many purposes because it cannot be operated when the air temperature falls below the freezing-point of water. Short periods of such low temperatures, a few hours in length, produce an ice or frost coating over the cup; longer periods destroy the instrument with the bursting of the cup through freezing of the contained water. For measurements of evaporation under such conditions of cold the only instrument so far employed at all is the open pan of water, which thus exposes a free surface of solid water, or ice. Measurements are usually made by weighing.

In connection with this matter it is to be observed that the freezing of a free water surface is another modification of the instrument, somewhat similar to dust accumulation, wave formation, etc. Evaporation does not progress at the same rate from an ice surface as from an equal surface of liquid water, at the same temperature,[15] so that when freezing occurs it is as though the instrument itself were profoundly altered. Thus there is no logical direct comparison to be instituted between readings made with the liquid surface and those made with ice. Difficult as the problem thus raised undoubtedly is, the importance of winter evaporation is so great that some rational method for its measurement should be devised. We cannot go further at the present time than to state that there is no method yet described, suitable for measuring evaporation during periods of frost; porous cups burst and leave blanks in the record, open pans freeze and introduce misleading readings into the record, readings which are not directly comparable with those from the same instrument with liquid water.

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[15] Juhlin, J., Bestämning af Vattenångans Maximi-spänstighet öfver is mellan 0° och – 50°C. samt öfver flytande Vatten mellan + 20° och – 13°C. Bihang K. Svensk. Vet.-Akad. Handlingar **17**[1]: 1–72, 1891.

Marvin, F., Report of vapor pressure measurements and normal barometer construction. Part I. Maximum pressures of aqueous vapor at low temperatures. Ann. Rept. Chief Signal Office, Washington, **1891**: 351–383, 1892.

## THE POROUS CUP ATMOMETER

### *The Porous Cups*

The atmometer cups now generally used in ecology, agriculture and forestry are practically of the same form and size as those described by the writer in 1906. The only improvement has been to make the closed end more nearly hemispherical, less pointed, than was the case at first. This change was made in 1913. These cups are cylindrical, about 13 cm. long and 2.5 cm. in diameter, closed at one end and strengthened at the other by a thickened rim. The wall is from 3 to 4 mm. thick, with the exception of the rim, which is about twice as thick. They are white, with a smooth, porous and absorbent exterior surface. The cup is closed, in use, by a rubber stopper which bears the tubing connection to the reservoir.

Since it is absolutely essential that the evaporating surface change as little as possible, it is unsafe, in handling, to allow contact of the hands with the porous surface. To avoid the necessity of this, the basal portion (at the open end) of each cup is made water proof; details of manufacture have so far made use of a glaze for this purpose impossible and ordinary orange shellac in alcohol has been mostly employed as coating. Melted sulphur, into which the previously heated cup is dipped, gives a more serviceable coating, in some respects, but its application is somewhat troublesome. Before the coating is put on each cup is numbered on its rim, so as to be easily identified in use. The dipping in shellac is repeated till a satisfactory covering is obtained.

The original standard cup of 1907 was free of coating for a length of 6 cm. from the closed end. Some cups were still more highly coated, but it was found more advantageous to have a large evaporating surface (both because of reduced error in reading and because the larger surfaces remain without serious alteration for a much longer time), and most of the cups used and distributed for the last five years have had uncoated portions 8 cm. long. Thus the evaporating cylinder has the last-named length, an outside diameter of about 2.5 cm. and a hemispherical closed end, the whole being continuous below with the nonporous remainder of the cup.

Other sizes and shapes of cup have been described from time to time and some of these have been furnished to the market. Yapp's[16] and Transeau's[17] cups differ from the usual one in minor points, but neither of these has come into very general use. The present writer has been able to procure, especially, two other cups, which have been placed upon the market. One of these, the insoluble cup, is of about the same form as the regular one, somewhat smaller, and made of a much more resistant material. In future this will have the same size and form as the regular cup. It has a glazed base, making shellac unnecessary. The other cup mentioned is termed "thin-walled." It is a straight cylinder 14 cm. long, 1.8 cm. in diameter, closed above by a somewhat flattened top and glazed at the base to a height of 2.5 cm. This was obtained largely for its very thin wall, about a millimeter in thickness, which suits it to certain comparative studies which need not be discussed here. Both of these special cups are now obtainable in pure white, though earlier lots of the insoluble form were slightly yellowish in color. The two smaller forms were designed for special uses.

### *The Standardized Cup*

The main feature which has given the porous cup atmometer its present importance as an instrument of research is that it can be standardized and that standardization may be repeated as often as is desired. The cups are standardized by operating them with pure water, along with a cup of previous standardization, upon a rotating table,[18] either indoors or in the open—in the latter case, without rain. Where radio-atmometers (which receive attention below) are employed, sunshine must be excluded, as well as any other form of strong radiant energy. To accelerate evaporation, and thus give larger readings for shorter time periods, an electric fan is frequently so placed as to pass a strong current of air across the rotating table. The results are the same, aside from the time required, whether the fan is employed or not.

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[16] Yapp, R. H., On stratification in the vegetation of a marsh and its relation to evaporation and temperature. Ann. Bot. **23**: 275–319, 1909.

[17] Transeau, E. N., A simple vaporimeter. Bot. Gaz. **49**: 459–460, 1910.

The rotating table now in use in the Laboratory of Plant Physiology of the Johns Hopkins University is somewhat over 2 m. in diameter and rotates two or three times per minute. At the Desert Laboratory Mr. J. W. Shive constructed, in the summer of 1913, a rather similar but smaller table, about 130 cm. in diameter, built upon a single bicycle wheel in a manner somewhat similar to that adopted by Nichols.[19] It makes no difference, as far as these matters have been studied, what size of table is employed or at what speed it rotates.

Of course the purpose of the rotation is to give the various cups equal treatment; since it is practically impossible to maintain exactly similar or even constant air conditions throughout a group of stationary cups, this is not attempted, but each individual cup is made to march through the same series of conditions as does every other cup of the group. The principle of this procedure is related to that upon which is based the long familiar use of clinostats, to equalize one-sided influences, as these affect growing plants.

The cups may be mounted, for operation upon the rotating table, in any convenient manner, usually on small-mouth bottles or upon burettes (see the following section on installation), but it is to be borne in mind that every cup should receive the same influence due to the trailing vapor blanket emanating from the next preceding one in the series. This means that all cups should be at the same elevation from the table and that they should be equally spaced in the same circle.

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[18] Livingston, *loc. cit.*, 1912.

[19] Nichols, G. N., A simple revolving table for standardizing porous cup atmometers. Bot. Gaz. **56**: 148-152. 1913.

A group of cups, with one of previous standardization, are first operated without reading for a period of from 12 to 24 hours, to allow the water films in the walls to come into equilibrium, after which they are operated on the rotating table until the water loss from each is sufficiently great (say from 20 to 50 cc.) to make errors of reading negligible. The corrected reading of the cup of previous standardization is divided by that of each cup to be standardized, thus giving what is termed the coefficient of correction in each case. The coefficients are at once seen to be numbers by which the readings of the respective cups are to be multiplied, in order to give the loss which would have been shown from a cup with coefficient of unity, operated under the same conditions and for the same time. By "corrected reading" of the previously standardized cup is here meant the product obtained by multiplying the actual reading by the coefficient derived at the earlier test.

The group is operated for a second period and the calculations are repeated, giving a second coefficient in each case. Where the two coefficients thus obtained agree, or show differences not greater than 0.03, the cups are regarded as satisfactorily standardized. They are then removed from the table, dried and wrapped in paper, the cup number and the mean coefficient from the two tests being written upon the wrapper. Cups which show larger fluctuations in the value of the coefficient are left on the table and operated, with the same or other standard cups, till a coefficient is fixed upon, or until they prove themselves impossible of satisfactory standardization, in which case they are discarded.

The basis of standardization is still the old 6 cm. form of cup, but only for historical reasons. The first standardizations, carried out at the Missouri Botanical Garden and at the Desert Laboratory, in 1907, amounted simply to comparing the readings, under similar conditions, from a large number of 6-cm. cups. It was found that about half of these agreed very closely among themselves and that their water loss for any test was about the average loss from the entire group, some seventy-five cups altogether. The largest number of cups with agreeing rates were designated standards, and their coefficients were arbitrarily placed at unity. Thus those which lost more water had coefficients below 1.00 and those losing less had coefficients above 1.00. It was to individuals with coefficient of unity, as thus established, that the earlier 8-cm. cups were standardized, under the conditions of early summer in Tucson, Arizona, and the majority of this larger type gave coefficients of about 0.73. It is doubtful whether this coefficient would stand, as showing the relation of the 6-cm. to the 8-cm. cup, under all climatic conditions since the two instruments are not strictly of the same form, but only similar in certain respects. However, the 6-cm. cups are no longer in general use and the application of the coefficients of the 8-cm. standards now used simply reduces their readings to terms of an hypothetical cup, whose loss, under the same surroundings, is taken as $\frac{100}{73}$ of that from the average 8-cm. cup. For practical purposes, as far as experience has gone, it seems quite safe actually to standardize 8-cm. to 6-cm. cups, and *vice versa*, though the procedure is obviously objectionable on theoretical grounds and has not been latterly practiced by the writer.

The above explanation shows why it is, as some users of these cups may have noticed, that 6-cm. cups (about half shellacked) have coefficients approaching 1.00 when new, while the coefficients of 8-cm. cups, as now marketed, are in the neighborhood of 0.73. Actually, these latter values usually lie between 0.67 and 0.79.

In general it may be said that if the reading of any 8-cm. cup be multiplied by its coefficient the result is the same as though a large group of similar 8-cm. cups were operated under the same conditions as those obtaining around the one in question and the mean loss of the group were multiplied by 0.73. In other words, the average 8-cm. cup is now arbitrarily taken as having a coefficient of 0.73 instead of 1.00.

An important precaution in standardization arises from the fact that the porous clay surface is apt to alter with continued use. Such alterations become evident as change in the value of the coefficient, and may be due to dust accumulation, to salts from water not strictly pure, to salts from the porcelain itself, or to removal of the shellac coating, etc. To avoid the effects of this possible alteration of standard cups it has long been the practice to use a given cup as of known coefficient only once (for not longer than three days), or during the process of standardizing a single group of cups. The cup so used for the first group became a cup to be standardized and a member of the next group, the standard for the latter being a new cup, unused since its standardization at some previous time. Some of the cups whose coefficients from two periods of operation on the table agreed (coefficients are actually calculated only to the second place of decimals, for cups placed upon the market), were laid aside for future standards and a large stock of these was always on hand.

To insure clearness in regard to the calculation of coefficients, the operation may here be stated algebraically. If $R$ is the reading of the cup of known coefficient (the one used as standard) and this coefficient is $C$, while the corresponding reading of any other instrument in the group is $r$, then the required coefficient of the latter instrument ($K$), for this period of operation upon the rotating table, is deduced as follows: $K = \frac{CR}{r}$. Whenever this cup is used its readings are to be multiplied by $K$, to make them comparable with the similar corrected readings of any other standardized cup.

As has been already emphasized, it is theoretically possible to derive a coefficient of correction (for reducing the reading of one cup to what would have been the reading of another in the same time and place) only when the two cups compared have very nearly the same form, size, etc. As in other similar instances met with in physical science, the importance of this whole matter depends upon the magnitude of the differences involved. In the present instance it also depends upon the sort of study to be carried out. It is quite readily possible to derive a coefficient which will express the relation between the evaporating powers of any two cups as shown by their operation on the rotating table for, say, a single day. If the cups are not alike, however, hourly readings through the day may show that the value of the coefficient fluctuates from hour to hour, for all hours of the day are not alike in the atmospheric conditions which they present. The conditions presented by one hour may accelerate water loss from one cup more than that from the other; those occurring in another hour may accelerate loss from the second more than from the first, etc. Similarly, the average coefficient derived from operation on another day may be different from that first obtained. But if two days present the same march of hourly conditions, or if they are so related that the *average effective hourly conditions* for one are in agreement with the corresponding average for the other (although it may be that no hour of one day gives the same coefficient as the same or any other hour of the other day), then the coefficient derived on the two days should be the same. From this sort of consideration it emerges that, the more detailed the work undertaken, and the greater the range of external conditions dealt with, the more attention should be given to having the cups exactly alike.

For usual purposes of work in the field, experience points to the conviction that the 6-cm. and 8-cm. cups are not sufficiently diverse to make it practically impossible to reduce the readings of the shorter form to terms of loss from the longer, and *vice versa.* It is clear that these two forms are of the same shape, but the porous portion of one is 2 cm. longer than that of the other. The effect of various climatic complexes in altering the relation between evaporation rates from these two forms of cups is, at any rate, only slight, and has not been definitely brought out in standardizations carried out by night and by day in the summer of southern Arizona and indoors in the Baltimore winter. It is therefore safe to conclude that the corrected readings of the 8-cm. cups are at least practically comparable with the corrected readings of the 6-cm. cups formerly widely used. In spite of the theoretical difficulty here encountered, it may be assumed that the earlier results, obtained with 6-cm. cups, are practically homogeneous and comparable with the later ones obtained with the longer form. Thus, all published measurements of the evaporating power of the air, in so far as these have been corrected to the Livingston standard, may be regarded as comparable for all practical purposes, regardless as to whether 6-cm. or 8-cm. instruments were employed.

Further study of the behavior of these instruments, and of other modifications as to form and size, will be necessary before we shall be able to state within what sort of limits of external conditions the relation between the evaporating powers of two different kinds of cup may be considered approximately constant. Where the greatest accuracy is derived it is advisable to employ cups whose coefficients are alike.

This matter of cup size and shape has no reference, of course, to modifications of the cups, produced by dust, handling, impure water, etc., which are apt to occur with use. With these alterations we shall deal below, in considering the operation of the instrument. This is, however, the place to mention one feature of this general problem, which is involved in the standardization procedure. It has been stated that serious changes in the standard cup have been avoided by frequently replacing the standard with a new cup, unused since its standardization. It has also been stated that serious alterations in cup surface may usually be prevented by frequent cleansing. The question then arises, would it not be better to hold the same standard continuously and to cleanse it from time to time instead of replacing? This suggestion is perfectly feasible with the insoluble cup, which is permanently glazed at base, but is to be followed with caution in the case of the regular form. The latter has been thought to be soft enough so that repeated rubbing might alter the porcelain surface, and there is little doubt that such treatment would alter the shellac coating. Recently the new form of insoluble cup, quite like the regular cup in size and form, has been employed as standard. With thorough cleaning between standardization series, a single one of these cups may be repeatedly used.

(*To be continued.*)

# OBSERVATIONS IN THE COLORADO DESERT

S. B. PARISH
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An historic highway leads from Fort Yuma, on the Colorado river, to Warner's Ranch, situated at an elevation of 3000 feet in the mountains of San Diego county, California. In the early days of the American occupation it was the great thoroughfare from the regions beyond that river to the primitive settlements of southern California. Not until this grassy valley was reached did the weary traveler feel that the perils of the desert were passed, and a comparatively easy way was open to San Diego or Los Angeles. Several of the botanists connected with the early government surveys passed over this route, and places along it find mention in their reports. Later the construction of railways, and the building of another and better road, deprived the old one of its former importance, and at present it is little travelled. Early in April, 1914, the writer drove over a part of it, and the following notes, the last two excepted, relate to places situated upon it.

## SAN FELIPE

Five miles beyond the Hot Springs in Warner Valley, as one travels desertwards, the summit which divides the desert from the seaward mountains is passed at an altitude of 3780 feet and San Felipe Valley is reached. San Felipe is 1600 feet lower than Warner's, and both of them drain through steep canyons to the Colorado desert and the lower part of Carrizo creek. They are, therefore, part of the catchment area of the Cahuilla basin, but their flora, especially that of the first named valley, belongs largely to that of the arid San Diego Mountains.

Both valleys contain considerable areas of coarse grasses, and numerous herbs and shrubs which are common in the dry montane region. In addition there is much *Artemesia tridentata*, which is not common. But in San Felipe desert conditions prevail, manifesting themselves in the presence of Larreas, Fouquieras and Agaves. The species of the last named genus is *A. deserti* Wats. which extends in a broad belt from the base of San Jacinto mountain to the borders of Lower California, where it connects with *A. Palmeri* Wats. Trelease has proposed a second species, *A. consociata*,[1] for a part of the plants of this belt, founding it on specimens collected at San Felipe, but the characters relied upon were not recognizable in the field.

### LA PUERTA DE SAN FELIPE

At the lower end of San Felipe a narrow gorge affords a bare passage for vehicles through a rocky ridge. Formerly it bore the appropriate Spanish name which indicated that it was the portal of entrance to the valley, but now it is more prosaically known as "Box Canyon." On its rocky sides grow *Juniperus californica* and specimens of *Opuntia echinocarpa*, *O. chlorotica*, *Cereus Engelmanni*, *Echinocactus cylindraceus* and *Mamillaria phellosperma*. Other shrubs were *Lycium Cooperi*, *Condalia Parryi* and *Prunus eriogyna*. In narrow seams *Arabis perennans* and tufts of *Cheilanthes Fendleri* and *Chamæsyce polycarpa hirsuta* found root. Desert conditions are unfavorable to the growth of lichens, and where these prevail lichens are seldom present, so that it was interesting to find a number of crustaceous species in abundance on the more sheltered rock surfaces.[2]

### LA PUERTA VALLEY

The pass opens upon a small valley, whose gentle slope is abundantly grown over with Agave, intermingled with *Yucca Mohavensis*, Larrea and other shrubs. On the nearer side forbidding and arid mountains of low altitude divide it from Salton

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[1] Rept. Mo. Bot. Gard. xxii, p. 53, 1912.

[2] The following species were collected: *Acarospora squamulosa* (Schrad.) Th. Fr., *A. xanthophana* (Nyl.) Fink, *Buellia myriocarpa* (Lam. & DC.) Mudd. *Dermatocarpon hepaticum* (Ach.) Th. Fr., *Gyrophora grisea* Borr. & Turn., *Parmelia conspersa* (Ehrh.) Ach. and its var. *isidiata* Neil.

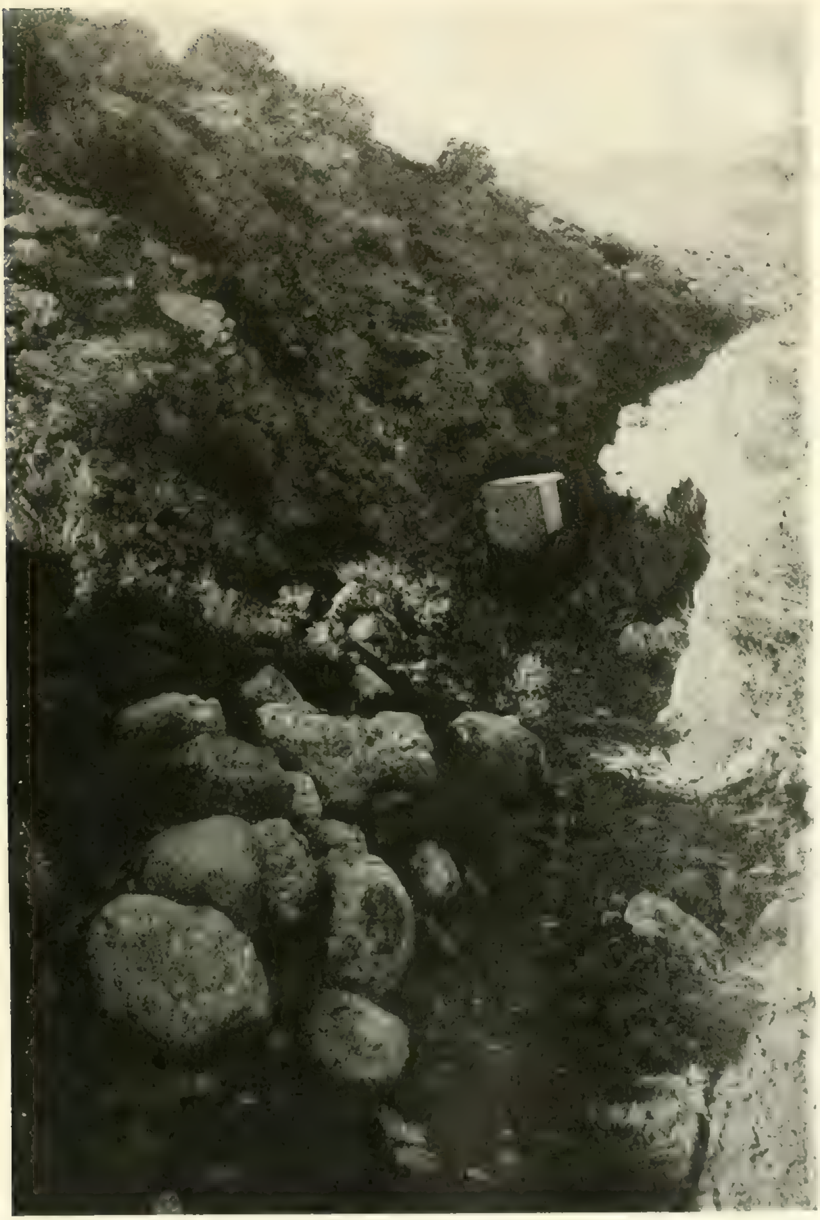

Fig. 1. La Puerta de San Felipe, between La Puerta and San Felipe Valleys

Basin; opposite a steeper ascent flanks Pine Lake Mountain, on whose summit small conifers can be discerned. Climatic conditions are austere in this valley. The range of temperature is from 15 to 115 F., and the rainfall, which is very uncertain, from 3 to 6 inches per year, while the violence of the winds is manifested by the sand heaped in the lea of every obstacle. But with all this, vegetation is more abundant and varied than in the still more arid desert beyond.

The Agaves do not extend to the center of the valley, which is nearly flat. Here stunted Larreas constitute the principal growth, subordinate shrubs being *Lycium Andersonii* var. *Wrightii*, *Hymenoclea salsola* and *Croton californicus*. They afford some shelter to a number of annual herbs: *Abronia aurita*, *Dithyrea californica*, *Coreopsis Bigelovii*, *Lupinus gracilis*, *Oenothera pallida*, *Nama demissum*, *Baeria gracilis*, *Pectocarya linearis*, *Salvia carduacea*, and others past recognition. The only introduced plants noted were *Erodium cicutarium* and a little *Bromus rubens*, both much reduced in size, as were the native herbs.

The soil in which the above plants were growing is a washed sand, much of it coarse, but further down the valley it is finer and loamy, and evidently contains some alkali. Here the plant most in evidence was a low form of *Atriplex canescens*, which had been closely browsed by cattle. There were also a few small mesquites (*Prosopis glandulosa*), some growing free and others buried in low dunes. All were alike leafless, a testimony to the severity of the winter climate. In this soil herbs were almost wholly absent.

The slope toward the higher mountain on the southwest side of the valley is exceedingly rough with rocks, both in place and in strown fragments, and is cut up by shallow ravines. The vegetation exhibits a manifest zonalization. To the Larreas of the valley floor succeeds a nearly unmixed belt of a shrubby Eriogonum, whose glaucous foliage gives it a slaty-blue aspect. As it was not yet in flower the species could not be determined. This was succeeded by a mixed chaparral, in which *Condalia Parryi* and *Prunus eriogyna* were markedly dominant. Next in prominence was *Rhus ovata*, large and vigorous, and as subordinate shrubs *Simmondsia californica*, *Stenotus linearifolia*, *Salvia apiana* and *Eriogonum fasciculatum*. *Opuntia basilaris* var. *ramosa* and two spinose platopuntias in many places obstructed passage. Among the stones scattered over the surface grew *Pellaea ornithopus*, *Cheilanthes Fendleri* and a small Dudleya. Along the main drainage wash, now dry, but doubtless having some percolating underflow, were a few small cottonwoods (*Populus Fremonti* var. *Wislizeni*) and sycamores (*Platanus racemosus*), and thickets of *Baccharis sarothroides*.

Only at this place has the writer found the sycamore on the desert side of the mountains, but a consideration of the plants growing on this slope will show that, with two exceptions, they all are to be found in greater or less abundance on the cismontane side. This is in marked contrast to the vegetation of the hill on the opposite side of the valley, which belongs to the exclusively desert flora.

The two exceptions above referred to are *Prunus eriogyna* and *Condalia Parryi*. These two species are often companions, and are found in numerous places, at from 500 to 2000 feet altitude, along the flanks of the range bordering the desert, from Whitewater, at the eastern base of San Gorgonio mountain, at least to the Mexican border. The Prunus seldom exceeds 6 feet in height, and is always a shrub. As seen at this place most specimens contained much dead wood, and the general aspect suggested that their struggle for existence was difficult. Condalia, while often shrubby, is properly a tree, reaching a height of 15 feet usually with a single trunk. Both were loaded (April 1) with fruit more than half grown.

Time did not permit the ascent of the mountain slope beyond 1000 feet above the valley floor, but to have continued it would doubtless have revealed instructive and interesting successions.

## VALLECITO

The road which descends into the desert follows the course of Carrizo creek, a typical desert "wash," whose sand-filled channel carries water only as the ephemeral sequence of a torrential thunderstorm. Yet in its depths percolates water which in places may come to the surface as a short stream, or sufficiently near to subirrigate a patch of grasses or sedges. Carrizo creek, being a wash which represents the drainage of an extensive basin, has not only its present wide sandy bed, but in former times has built a valley of considerable width, save where it has been obliged to cut its way through obstructing cross ridges.

Through such a gorge La Puerta was entered from San Felipe, and through a lesser one Vallecito is entered. One emerges from this pass upon a wide and gentle bajada covered with a fine growth of large and vigorous Fouquieras, their long stems closely clothed with foliage from base to apex, from which the scarlet streamers of blossom were beginning to float. They were set unusually near together, and only a scanty growth of low shrubs was scattered in the intervals.

Six miles below the pass a slender stream moistens a little flat of salt grass. About it grow *Atriplex lentiformis*, *Pluchea sericea*, *Suaeda suffrutescens* and *Isocoma veneta* var. Beneath a group of cottonwoods were the ruins of the old stage station, an adobe hovel, one side of which had been occupied by men and the other by mules.

## PALM SPRINGS

The road now follows the sandy bed of Carrizo creek, along and in which there is a scattering of *Parosela spinosa*, or the bordering bench, which is thickly overgrown with Agaves. The flower scapes were just shooting up, many of them eaten off by hungry cattle. Fouquieras continued abundant, and at this place (alt. 1200 ft.) the leaves were turning red and falling, while the plants were in vivid bloom; lower in the desert the stems were found quite leafless, but flowering continued. There was a good representation of the usual low desert shrubs, mostly isolated individually by bare intervals. The number of species was limited, the most prominent being *Larrea Atriplex canescens*, *Hymenoclea salsola*, *Franseria dumosa*, *Parosela Emoryi* and *Opuntia Bigelovii*, the last gregarious in small groups. *Abronia aurita* and *Lupinus arizonicus* were the only noted herbs.

The springs themselves consist of some seepages of fair water which moisten a small tract, gratefully green with a sod of *Distichlis spicata, Juncus balticus* and *Scirpus americanus.* A ditch has been cut, through which the seepage is conducted to a small tank, and both ditch and tank were full of *Xannichellia palustris,* in which Lemna and Chara were entangled. The borders were enlivened by the yellow buttons of *Cotula coronopifolia,* a common introduced plant of the cismontane region, but not seen elsewhere in the desert. A group of mesquites afforded a grateful shade. They were here in full leaf and flower.

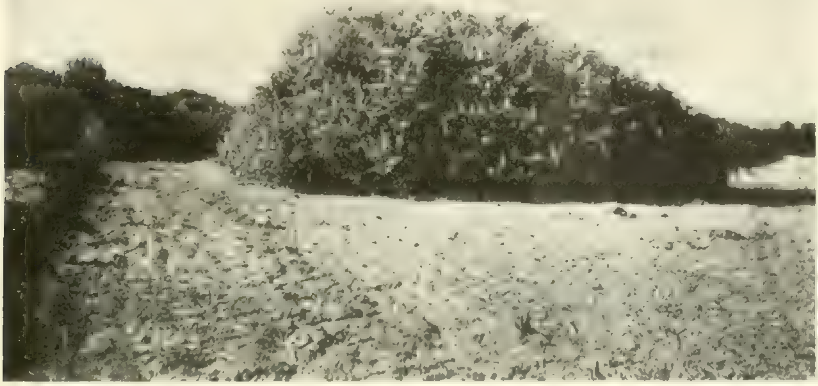

Fig. 2. A characteristic specimen of *Atriplex lentiformis,* growing in strong and moist alkaline soil. Others in the background.

There is another and better-known "Palm Springs" at the base of San Jacinto mountain, which should not be confused with this one. This is the spring mentioned in the report of Emory's Reconnaissance, where, on November 28, 1846, the weary explorers were cheered by the sight of "cabbage trees," and recorded the first mention of the Washington palm to be found in print. Long ago vandals cut down the few trees which grew here, but people remember seeing the stumps, for which we searched in vain among the dense thickets of Atriplex which occupy the alkaline soil surrounding the spring borders.

## CARRIZO CREEK

Carrizo is the name used by the Spanish-speaking Californians for *Phragmites communis*, an occasional grass in wet alkaline soils in the Colorado desert, but not seen along the wash to which it gives a name. Emphatically Carrizo creek indicates that part of the wash, 10 miles beyond Palm Springs, where by the configuration of the bedrock the percolating water is brought to the surface, giving rise to a large tract of damp ground, from which drains a small stream of tepid and slightly alkaline water, soon lost in the thirsty sands. The altitude is 600 feet above sea level, and the place is easily identifiable with the "Ojo Grande" of Emory's report.

The damp soil is tainted with saline matter, and supports a sod, mainly of *Distichlis spicata*, with a smaller percentage of *Juncus balticus*. Where there are shallow pools they are filled with *Typha latifolia* and *Scirpus americanus*, and about them grow clumps of shrubby willows. In one of them some Chara was present. In the dryer alkaline soil was the usual growth of Isocoma, Suaeda and Atriplexes.

In following the course of the wash from Palm Springs Agaves are no longer seen beyond a point about half way to the marsh, and at an altitude of about 800 feet. The mesas were sparsely occupied by common desert shrubs, such as *Larrea*, *Parosela Emoryi* and *P. Schottii*, and the everpresent *Atriplex canescens*. A less frequent shrub, *Encelia fruitescens*, abounded, growing in a compact rounded form, 1–2 feet in diameter, densely leafy, and projecting its solitary rayless flowers on short peduncles.

## SPLIT MOUNTAIN

Below the Carrizo marshes the road passes over a rough mesa, dotted at wide intervals by stunted Larreas and Atriplexes, relieved by no occasional herb. On either hand are low ranges of mountains of baked mud, deeply seamed and barren. The bed of the wash occupies the middle ground, a wide sandy waste, where an occasional Chilopsis or a Mesquite mound afforded the only touch of verdure to relieve the lifeless scene.

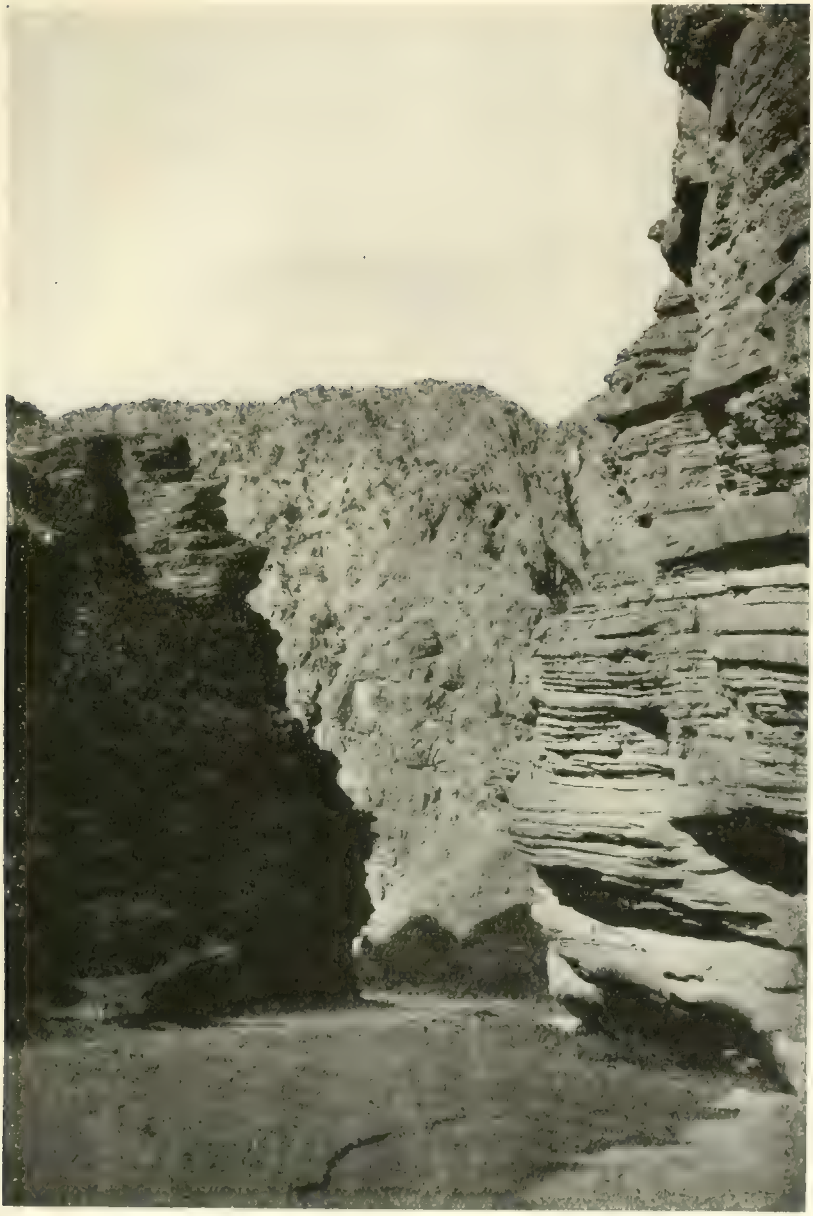

Fig. 3. Split-Mountain Canyon.

After travelling some 4 miles through this desolation the old road, which continues along Carrizo creek, was left in order to visit the canyon of Split Mountain, on the other side of the range, and opening directly upon the Salton Sink. The way, for it cannot be called a road, is to be followed only by a careful watch for an occasional half-effaced wheel mark, or a monument made by placing a cobblestone atop a boulder. By such uncertain indications one is guided through the right branches of a sand wash, all of which appear exactly alike.

The vegetation was sparse, and consisted of the same monotonous shrubs already so often mentioned. The extreme aridity was emphasized by the absence of Agaves and Cactaceae. Toward the upper end of the wash were tufts of *Aristida bromoides*, *A. Parishii* and *Pleuraphis rigida*, too few to affect the general barrenness.

As the summit is neared ledges project composed of small oyster shells closely compacted. The divide itself is a wide expanse of grayish clay, cut by ravines hundreds of feet deep and precipitously steep. The pathway follows the ridges, so narrow as barely to afford a precarious passage. The barrenness of the clay is untouched by a trace of vegetation. At last a slope is reached down which it is possible to descend to a wash leading to the canyon.

Split canyon well deserves its name, since it seems an enormous crevice riven into the heart of the mountain. For a mile or more its perpendicular walls of sandstone and conglomerate tower hundreds of feet on either hand. The floor is from 100 to 300 feet in width, and in places is so littered with great angular blocks of stone that it is with difficulty that passage for a wagon is found between them. Plant growth was very limited, both in species and in individuals. Among the rocks were *Hyptis Emoryi*, *Parosela spinosa* and *Acacia Greggii*; and a few herbs, *Chamaesyce polycarpa*, *Achyronychia Cooperi* and a desert form of *Hosackia strigosa*, spread their radiate stems upon the sand. With them grew some clumps of *Astragalus limatus*, and along the base of the cliffs *Aster Orcuttii*, *Physalis crassifolia* and *Oenothera cardio-*

*phylla*, all common in the desert canyon. Rarer plants were *Calycoseris Wrightii* var. *californica*, *Coldenia brevicalyx*, *Malperia tenuis* and *Astragalus sabulonum*.

## MOUNTAIN SPRINGS

Mountain Springs is in San Diego county, almost on the line dividing it from Imperial county, and some 5 miles from the Mexican boundary. A steep escarpment here divides the Colorado desert from the confused region of mountains, seldom exceeding 5000 feet in altitude, which reaches to the shores of the Pacific. An excellent road, cut in the rocky sides of Myers' canyon, is the artery of travel between Imperial valley and the port of San Diego. On the desert side it is approached from Coyote Wells, the altitude of which is only 225 feet. An ascent of 865 feet in a distance of 6.5 miles intervenes to the base of the mountain wall. Thence to the springs (alt. 2370 ft.) is 5.5 miles and a rise of 1260 feet, and from there to the summit 3.5 miles and a rise of 861 feet, making its altitude 3231 feet above sea level.

These data will convey some idea of the extreme abruptness of the desert rim at this part of its course, and this will be more evident when it is remembered that the canyon mileage is measured along the road, which by its convolutions attains an easy grade, so that the direct incline would be no more than one-fifth of the road distance. It is evident, therefore, that there is here compressed in a short space a difference of altitude which should manifest itself by a corresponding differentiation of the plant population.

Such differences exist, but not as marked as might be expected were certain other factors not taken into consideration. There are no records of the rainfall at Mountain Springs; probably it is slightly, but only slightly, greater than that upon the open desert beyond. The temperature, especially in winter, must be somewhat cooler. But it must be remembered that this precipitous canyon faces the burning Salton Basin, while behind it are low mountains whose aridity is little modified even to the borders of the sea. The passage is not from one phytogeographical region to another, but between two differentiated subdivisions. The differences here are mainly those of altitude, which does not appear to be of primary importance.

The rocky nature of the substratum, almost destitute of soil of any kind, provides a place for plants whose root systems are altogether different from that of those growing in any of the soils of the basin. But the vegetation is of the same extreme xerophytic type prevalent throughout the whole region. In point of fact there grows here but a single species which is not found elsewhere in these desert mountains. The distinguishing feature is the comparative abundance of the flora. Only in some of the canyons which descend from the San Gorgonio or the San Jacinto Mountains is it more varied and abundant.

This is most apparent to one who approaches it from the desert. For weary miles he has toiled through a dreary monotony of unattractive low shrubs, isolated by wide bare spaces. At Coyote Wells he has found a patch of salt grass, and a few wretched mesquites. Beyond lay a still more naked waste of sand. To one thus coming the canyon vegetation appears notably varied and pleasing.

It is a matter of regret to the writer that he was not able to devote more time to the study of this interesting canyon. It deserves days, rather than the hours he was able to give to it. While the conditions produce a crowding together and commingling of the various plants, a careful study would enable one to define their several topographical limits. In the absence of this only a partial account can be offered.

The plants which most attract attention by reason of their size are *Fouquiera splendens*, *Yucca moharensis* and a species of *Nolina*, the flowers and fruit of which have never been collected at this place, but which has been referred on foliar characters to *N. Bigelovii* Wats. The species was founded by Torrey (as *Dasylirion Bigelovii*) on a specimen from Bill Williams River, Arizona, and according to Trelease it has also been collected in Cantillas Canyon, in adjacent Lower California.[3] In California it has been collected only at Mountain Springs. The trunk is 1–5 feet high, and the few dry remains of infloresence were about 3 feet tall. It is desirable that fruit and flowers should be collected at this station.

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[3] Torrey, Pac. R. Rept. iv, pt. 5, p. 151. Watson, Proc. Amer. Acad. xiv, p. 247. Trelease, Proc. Amer. Philos. Soc. L, p. 423.

The three shrubs mentioned are plentiful in the neighborhood of the Springs, growing among the rocks of the little benches of the canyon. With them grow *Ephedra nevadensis*, a small shrub, and *Thamnosma montanum*, and *Mirabilis californica aspera*, two suffrutescent xerophytes. All might well be included among the petrophytes, which, since granitic rocks afford much the greater part of the substratum, constitute the most of the flora. Lithophytes, so far as the hasty examination permits one to speak, were not in evidence; but as the rocks are full of seams, and the ravines offer a variety of aspects, chasmophytes abound. Among them are *Dudleya pulverulenta*, *Echinocactus cylindraceus*, *Mamillaria phellosperma* and one or two *Platopuntias;* together with *Fagonia californica* and *Hofmiesteria pluriseta*. The sporophytes were represented by a sterile *Selaginella* of the *S. rupestris* group, and two ferns, *Notholaena Parryi* and *Cheilanthes viscida*, all abundant.

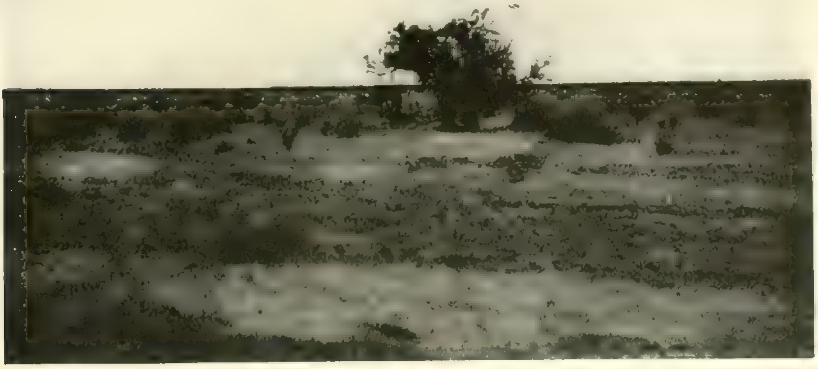

Fig. 4. A Mesquite near the border of a dry channel. Its appearance indicates an insufficient water supply.

Some distance above the Springs a bed of sand fills the channel for a short space where the descent is slight, and in it grows an unaccustomed fellowship of plants. A few scrub oaks and shrubby willows (*Quercus dumosa* and *Salix laevigata*) have passed over from the further side of the summit, while numerous robust clumps of *Juncus acutus* var. *sphaerocarpus* represent a still more distant horizon. This rush is abundant immediately along the coast, and according to the books does not extend beyond the neighborhood of the sea. It is, however, one of a small number of plants which are plentiful within the influence of the moist sea air, and then disappear from the intervening territory, to reappear in small numbers in one or two places on the desert borders.[1] In view of their extreme rarity in the latter habitat, which they evidently find uncongenial, it may be possible to regard them here as relict plants of a flora which, at the time when the trough of the desert was an arm of the sea, must have differed somewhat from the present.

The principal representatives of the desert flora were *Chamaesyce setiloba*, *Salvia Vaseyi* and a Sphæralcea which has been doubtfully included in *S. ambigua*. It is occasionally found in the desert mountains, and always along the borders of the washes within the canyons, and its numerous slender stems, 1–1.75 meters long and its light purple flowers, present a very different facies from that of the shorter and stiffer stems and the brick-red flowers of *S. ambigua*, which is distinctly a mesa or hillside plant. The field botanist will not be satisfied to include it in that species, but as no strictly technical character has been found to separate it, its final disposition may best be left to a monographer of this difficult genus.

The summit of the canyon is of coarse decomposed granite. In it grew an abundance of *Gilia pungens* var. *Hallii* and *Astragalus Vaseyi*, and a few specimens of *A. coccinea*, the most brilliant species of the genus.

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[1] The others are *Adiantum emarginatum*, *Saxifraga Parryi*, *Stemodia durantifolia* and *Nemacaulis Nuttallii*. All these, as well as the Juncus, occur sparingly at Palm Springs, at the desert base of San Jacinto mountains, and Nemacaulis, but none of the others, has been collected on Carrizo creek.

# BOOKS AND CURRENT LITERATURE

A Text-Book of Biology.—Most of us have used and all of us have admired Sedgwick and Wilson's text book General Biology. A new volume "based upon" this text book and written by Professor Calkins raises high expectations but, upon reading, one is disappointed. The book[1] is carelessly written and needs thorough and extensive revision before it can be accepted as a substitute for the still very usable older work.

The plan of the book is best told by the headings of the chapters:

Introduction. (Classification of the Biological Sciences.)

Chapter I. Living and Lifeless Matter. (Abstract treatment.)

Chapter II. Protoplasm and the Cell, and Organisms of One Cell. (Yeast, Bacteria.)

Chapter III. Organisms of One Cell, continued. (*Amoeba*, Flagellates, *Paramecium*, Biological Problems i.e. Animals vs. Plants, Spontaneous Generation, Age and Death, Fertilization.)

Chapter IV. Organisms of Tissues. (*Hydra*.)

Chapter V. Plants. (Nutrition, *Pleurococcus*, *Sphaerella*, *Pteris*.)

Chapter IV. Organs and Organ Systems. (Earthworm.)

Chapter VII. Homology and the Basis of Classification. (Lobster.)

Chapter VIII. Parasitism: Physiological Adaptation. (Tape-worm, Phagocytosis, Immunity.)

Chapter IX. The Perpetuation of Adaptations. (Heredity and Evolution.)

Excellent features in the book are its illustrations (except that on p. 152 which shows inaccurately the sperm ripening pouches of the earthworm, and figure 39 which shows too little to be of interest), and its treatment of Mendelism and other phenomena of inheritance in the last chapter. Its most serious defects are its frequent failures to approach a subject first by concrete illustrations before presenting a digest of the matter, numerous instances of inaccurate statements or statements of doubtful validity, some instances of confusion of thought or statement, lack of clearness due to insufficient exposition of some subjects mentioned or to vagueness of statement, occasional wrong use of words, frequent poor English, all or nearly all due doubtless merely to lack of care in the preparation of the book. A fuller treatment of several of the types and of some of the general conceptions would be advantageous.

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[1] Calkins, Gary N., Biology. Pp. 241, figs. 101. New York, Henry Holt and Company, 1914.

As inaccuracies note p. 70, conjugation a phenomenon universal in animals and plants; p. 50, contractile vacuole of *Amoeba* heavier than protoplasm; p. 47, acidity of liquid in gastric vacuoles of *Amoeba* due to digestive *ferments;* p. 38, the scattered granules in bacteria are chromatin; p. 80, minimum number of tentacles in *Hydra* 8; p. 91, no specialization of functional nervous fibres found in Protozoa (*cf.* Sharp on *Diplodinium*); p. 103, cellulose a distinctive plant product (cf. p. 65); p. 171, gill formula for Crawfish [this is of course different in *Astacus* and *Cambarus*]; p. 176, ears of lobster called auditory organs; p. 180, a lobster detaches its muscles from the exoskeleton before shedding the latter; p. 180, the lobster leaves the egg as a young lobster, reaching the adult condition by growth; p. 194, scarlatina affects man only [cows are also susceptible]; p. 201, Darwin treats natural selection as a *source* of variations; p. 139, cilia absent on endodermal cells of typhlosole of earthworm; p. 168, only digestible material enters the pyloric stomach of lobster; p. 173, the duct of the green gland in the lobster opens on the basal joint of the antennule; p. 161, "When organs have the same ancestry, that is when they come from some common part of an ancestral animal, they are said to be *homologous*" [this definition of course does not include the serial homology in the appendages of the lobster mentioned by Professor Calkins on the same page]. There are numerous other instances.

As statements of doubtful validity note p. 71, conjugation "a process of protoplasmic reorganization followed by renewal or re-birth of all vital activities including that of reproduction" [by the way, the German custom of distinguishing between conjugation and copulation is not followed by Professor Calkins]; p. 61, *Paramecium* is covered by a *lifeless* pellicle; p. 32, processes of nutrition in yeast primitive; p. 186, the scolex in the tape worm anterior [for what appears to be a demonstration of the inaccuracy of this statement see Kofoid on *Gyrocotyle*]; p. 187, proglottids of tape worm not metameres [cf. Kofoid on *Gyrocotyle*]; p. 231, "The history of the earth as written in modern geology allows some hundred millions of years for modern types to have evolved." [The planitesimal hypothesis greatly extends this possible time. Of course the earliest fauna and flora we know may have been preceded by many of which we have no record.] There are many similar instances.

Examples of omission—exoskeleton of earthworm and the cuticular lining of stomodaeum not mentioned; the valves in the blood vessels of the earthworm are not mentioned; polymorphism in hydroids and the character of medusae, if mentioned at all, should at least be figured; the water currents in the branchial chambers of the Crawfish are insufficiently described. Many other examples of insufficient treatment might be given.

But I must not prolong this detailed list of defects. Over one hundred and twenty-five were noted in a hasty reading. Of these I have mentioned here only a few instances of three of the many types of such defects. The main criticisms of the book are for inaccuracy and lack of clearness due to carelessness, for failure to approach the several subjects in a way natural and fully intelligible to a beginning student, in some instances for poor choice of and arrangement of material, and for insufficient development of some themes. It is difficult to see why Professor Calkins should care to write the book at all if he were not ready to give to it the attention necessary to success. To properly supplant the older work of Sedgwick and Wilson the book not only must be more carefully written but must also be better planned. Few men could do this better than Professor Calkins if he really cared to do it.

MAYNARD M. METCALF.

ABSCISSION.—The autumnal fall of leaves is the most generally known example of abscission. However other plant parts may be shed, among which may be mentioned embryo plants, as is the case in viviparous species of *Rhizophora*, *Podocarpus*, and *Tillandsia*, stem segments which often include large branches, as in *Salix*, *Populus*, and *Castilloa*, tendrils, as in *Ampelopsis*, bud scales and stipules, spines, as in certain cacti, flowers and their parts, and fruits, the most classic examples of which, perhaps, are cotton squares and bolls. Various investigations have recorded the occurrence of shedding and have sought to explain the causes of abscission. Two recent papers by Lloyd[2,3] not only bring together these results but very materially contribute to our knowledge of this interesting phenomenon. Attention is given to

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[2] Lloyd, F. E., Abscission. The Ottawa Naturalist **28**: 41–52, 61–75, 1914.

[3] Lloyd, F. E., Injury and abscission in *Impatiens sultani*. Sixth Rep't. Quebec Soc. Protection of Plants, 72–79, Pl. 1, 1914.

external factors such as temperature, humidity, water content of the soil, mechanical injuries due to shaking and wounding, toxic gases, and light, and to such other factors as the time required for separation to occur and the mechanism and method or manner of abscission. As a result of this study of more than thirty species of plants it is concluded that chemical changes (perhaps enzymotic) are always present in the abscission layer to some extent whether growth and turgor changes intervene or not. Weisner, Kubart, and Loewi regard turgor as the more important factor in effecting separation and believe that chemical changes may in some cases be absent. In *Impatiens* and *Ampelopsis*, at least, Lloyd finds that the abscission cells show no higher osmotic equivalent at the time of abscission than adjacent cells. By the use of 5% KOH the walls of the abscission cells in *Cheiranthus* could be made to simulate autolysis.—FREDERICK A. WOLF.

## NOTES AND COMMENT

At the Princeton Meeting of the Association of American Geographers, in December 1913, a paper was presented by Mr. W. L. G. Joerg in which he reviewed all of the leading attempts at a subdivision of North America into natural regions. In the recently published text of this paper (Annals of the Association of American Geographers, Vol. 4, p. 55) the author shows that the principal criteria for such maps have been taken from physiography, orography, climate, and the distribution of plants and animals. He has brought together a series of 21 maps showing the proposals of as many workers for the subdivision of North America, or of the United States, on the basis of some one of these criteria, or on a composite basis of all of them. Mr. Joerg adds a map of his own, which he speaks of as "selective" and "tentative," showing the natural areas of North America.

Such a tremendous diversity is exhibited by the maps collected by Mr. Joerg that it is almost surprising that the members of the Association had the courage, at their last meeting in Chicago, to conduct a round-table conference on the subject of the proper methods and criteria for the delineation of physiographic provinces in the United States. There is at least some hope of achieving acceptable maps of physiographic or climatic provinces, provided it is possible to unify or compromise the divergent view-points of all the physiographers or climatologists. Students of regional problems in botany and zoology will have considerable use for such maps, provided they are based strictly on the features which they are supposed to depict. A map of climatic provinces like that of Köppen, for example, which is based to a great extent on vegetational criteria, can be of little use to a plant geographer, unless he enjoys the intellectual exercise of reasoning in a circle.

The construction of a map of natural regions is a much more difficult undertaking, and largely because it is a less definite one. The map proposed by Mr. Joerg is a very careful piece of work and might serve fairly well as a map of climatic, physiographic, or biotic regions. In fact it differentiates climate better than the purely climatic maps of Supan and of Hult, and it makes a better map of vegetational areas than that of Hardy, which is based on vegetation alone.

The Geological Survey of South Dakota is continuing its work on the biological features of that state, its most recent bulletin being a report on Harding County, embracing a description of the vegetation and a list of plants, birds, and mammals. Throughout the report the grassland is unhappily alluded to as "steppe," a term which is not properly applicable to any part of the United States.

Dr. L. Cockayne, of Wellington, has published for distribution at the Panama-Pacific Exposition a pamphlet of 35 pages describing a large number of New Zealand plants suitable for cultivation in the United States.

Prof. Dr. A. Burgerstein, of Vienna, has completed a revision of his well known text on the transpiration of plants, but states that he will be unable to publish it until the close of the European war.

# ATMOMETRY AND THE POROUS CUP ATMOMETER

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## III

### *Installation*

*The Absorbing Mounting.* For laboratory work, in rooms, green-houses, and in any exposures where rain and heavy dew will not be encountered, the simple absorbing mounting (see fig. 5) is to be recommended. This consists merely in a rubber stopper closing the open (lower) end of the cup and bearing, through a perforation, a rigid, insoluble tube (glass, hard rubber, block tin, copper, possibly brass), of about 6 mm. bore, which connects with the water reservoir below. The tube should project a few centimeters into the cup. On the longer free part of the tube is placed a perforated cork stopper, its larger end toward the center of the tube, as is the larger end of the rubber stopper. This cork should fit the tube tightly so as not to slide readily up and down. It has a small oblique groove (2-3 mm. wide and of the same depth) on one side; a reservoir bottle is provided to take the cork stopper, and when the latter is in place air can enter or leave the bottle through the open groove. The groove in the cork may be replaced by inserting through the cork a short tube of small bore, its projecting upper end reflexed in the form of an inverted J and loosely plugged with cotton. The bottle used is an ordinary one of narrow mouth, holding from 250 to 1000 cc. according to the requirements. The cork stopper is so placed upon the tube that the latter reaches nearly to the bottom of the bottle when the stopper is firmly in place. The cork should extend above the neck of the bottle far enough to give safe fingerhold, to avoid danger of moving the stopper upon the tube. A file mark upon the lower part of the bottle neck serves as a zero mark when filling the bottle.

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Of course the tube may be connected with the outlet of a burette at a lower level, so that accurate readings may be made directly. In such a case it is advisable to cover the open end of the burette with a suitable cap.

The bottle is first filled with distilled water. The cup is then filled to overflowing and the rubber stopper is firmly set in place. Then the cup is held downward and the tube is filled with water by pouring from the bottle, after which tube and cup are quickly inverted and the latter is thrust into the bottle, avoiding any entrance of air into the open end of the tube. The cork stopper is then firmly placed. It is desirable to allow from 12 to 24 hours to elapse before beginning the taking of readings, so that the water films of the cup may come into equilibrium. Where long periods elapse between readings (as of several days) the latter precaution may be omitted, with the introduction of but a comparatively slight error.

At the beginning of operation the cork stopper is loosened from the bottle, it and the tube are lifted high enough so that the lower surface of the cork is free from the bottle neck, and moved laterally as far as the tube will allow. The tube and cork are now lowered until the lower face of the latter rests upon the top of the bottle, leaving the bottle mouth open sufficiently, alongside the tube, to allow the pouring in of water. The bottle is now filled to the zero mark and the cork firmly replaced. At the end of the period of operation this method of filling the reservoir is again used, the water required being measured from graduate or burette. The amount of water thus required is the loss which has occurred for the period. The manipulation of the cork and tube (with the cup above), as just described, insures that at every filling the same amount of water in the reservoir will be displaced by the tube. When the cork is replaced the water level rises above the zero mark, but the next filling will be made with the cork and tube in the same position, so that there is no error thus involved. If, when the cork is forced into position, the cup becomes visibly wet on the outside, this means that the groove in the cork is stopped and requires enlarging. In pouring water into the bottle, care should be taken that air bubbles are not carried down so as to enter the tube on rising.

Where a burette reservoir is employed it will of course be necessary to fill only when this is nearly emptied. The burette is ordinarily used when observations are to be taken at frequent intervals. Filling the bottle reservoir from a burette allows an error of reading of possibly 0.2 cc., usually negligible where temperature changes are not taken into account (thermometer action, expansion and contraction of the water in the apparatus) and where readings are not too small. With the burette the error of reading is much smaller, depending upon its diameter and graduation, and the volume change due to temperature variations may also be made much smaller here than in the case of the bottle.

For very short periods of operation, as from minute to minute, it is convenient to prepare a horizontal, graduated glass tube of small bore and mount the cup upon one end of this, letting the other end dip into a vessel of water (see fig. 6). An air bubble is allowed to enter at the free end, to serve as an index which may be followed along the horizontal tube. This whole arrangement is practically the same as the potometer, employed in physiology to study rates of absorption of cut plant parts. Of course the tube may be calibrated so that units of its length may be converted into volume units.

As has been mentioned, the error of volume change due to temperature alteration in the water of the instrument is to be completely avoided by weighing the whole apparatus at each reading and obtaining the loss directly in terms of weight.

*The Non-Absorbing Mounting.* A feature of the porous cup atmometer mounted as just described, which it possesses in common with the open pan of water, is that the results are rendered more or less false by the occurrence of rain.

It has been pointed out that the reason for the cup remaining filled with water lies in the fact that the tiny water-air menisci which close the outer ends of the pores of the wall are not broken by air pressure of considerable magnitude. Miss Aleita Hopping, working in the writer's laboratory, has shown, indeed, that the ordinary type of atmometer cup, when its wall is wet with water, prevents the passage of undissolved air until an air pressure of from three to five atmospheres is applied. With such high pressures, and only with them, does the air force its way through the porous walls, driving out more or less of the imbibed water.

As the atmometer is set up for operating, the unbalanced air pressure exerted on the outside of the wet cup wall never amounts to more than a meter of water column, say 10 cm. of mercury at most, which is only about one-seventh of a single atmosphere. Thus the films in question are never strained so as even to approach the breaking point, and the pressure of the air is as completely removed from the water within the cavity as though the cup were of glass. On the water surface in the reservoir the full atmospheric pressure is freely applied, however, and this is sufficient to support a water column in the tube and cup many times as long as this column ever actually is in any operating instrument.

When rain falls upon the cup, however the menisci closing the pores are destroyed, the external water surface being built up through addition of water from without, so that there are now no menisci at the outer ends of the pore openings. The result is that the water surface comes to be a free one, situated some small distance outside of the exterior surface of the porous wall. This free water surface receives the full atmospheric pressure, which tends to drive water through the cup wall, with a pressure as great as that of the water column extending from the cup surface to the level of the water surface in the reservoir below. Virtually the whole apparatus now behaves as a porous clay filter with a water column below "drawing" water through it. The higher the water column of the instrument the more rapidly will water pass in, under these conditions.

The rate of absorption of the standardized 8-cm. cup, 30-cm. above the reservoir surface, when the cup is kept externally covered by water (as in a heavy shower) may be over 4 cc. per hour.[20] It is clear that such rates of absorption during rainy periods utterly destroy the value of the instrument as one for measuring the evaporating power of the air. As has been stated, the absorbing mounting above described is suitable only where rain and heavy dew do not occur; for of course dew formed on the cup is absorbed just as is rain. In moist times, of low evaporation rates, a shower lasting less than an hour may inject into the reservoir more water than is removed by evaporation during the entire remainder of the day. Hence the evaporation rate for that day, although evaporation actually occurred for almost the entire time, cannot be determined from the instrument.

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[20] Harvey, E. M., The action of the rain-correcting atmometer. Plant World **16**: 89-93, 1913.

To avoid this difficulty, and give to the porous cup atmometer its greatest advantage over the open pan of water, the non-absorbing mounting was devised[21] (see fig. 7). In its essentials the non-absorbing porous cup atmometer differs from the absorbing form only in the introduction into the tube, between reservoir and cup, of a simple mercury valve which allows water readily to pass from reservoir to cup but practically prevents any movement in the opposite direction. Figure 7 (reprinted here from the author's paper just cited) shows the essential construction of the non-absorbing mounting as usually arranged. The following description is largely drawn from the earlier publication.

Two glass tubes (*A* and *B*) extend downward from the rubber stopper, one of them reaching upward to the tip of the cup, the other only through the stopper. These tubes are slightly offset laterally, so as to allow the attachment of the remaining members. They are of small bore—1 mm. is sufficient—as are also the other two tubes mentioned below. Each of these tubes passes a 2-perforated stopper into a small shell vial (with round bottom, though this detail is not shown in the diagram). Tube *B* nearly reaches the bottom of the vial, tube *A* merely penetrates the stopper. Through the remaining perforation in each stopper extends a second tube (*E*, *F*). Tube *E* is bent, first laterally about 5 cm. and then downward. It reaches nearly to the bottom of both vial *C* and reservoir *G*. Tube *F* reaches only through the stopper (vial *D*) and extends about 3 cm laterally, where it ends free (the diagram shows it bent downward, but this is unnecessary). Tube *E* is supplied with a loosely fitting cork stopper, slipping upward and downward upon the tube. The reservoir *G* is treated as in the absorbing mounting already described, a file mark on its neck serving as zero point in filling. A metal support for the vials, tubes and cup and a protecting apron of waterproof cloth to prevent rain-water from entering the reservoir around the tube, are provided (not shown in the diagram).

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[21] Livingston, B. E., A rain-correcting atmometer for ecological instrumentation. Plant World **13**: 79-82, 1910.

Vials *C* and *D* are supplied with clean mercury to a height of 6 or 8 mm. and their stoppers tightly inserted. The stopper of the reservoir is raised, the bottle slipped to one side as far as the tube will allow, and filling occurs as in the absorbing form. A rubber tube is attached to the free end of tube *F* and suction is applied, causing water to rise from the reservoir, successively filling vial *C*, the porous cup and vial *D*, and lastly escaping into the rubber tube. Suction is continued till no more air bubbles enter this tube, when the latter is removed. The instrument is now ready for operation.

As water evaporates from the cup mercury rises in tube *B* and falls in tube *E*, until water from the reservoir passes freely from *E* to *C*, between the mercury and the end of the glass tube. The lost water is now supplied as usual from the reservoir, the column of mercury in the lower end of tube *B* remaining at a height of a few millimeters (depending on the height of the cup above the water level in the reservoir). Water cannot enter the cup from vial *D* and this vial remains filled, unless it is eventually lowered by slow evaporation through tube *F*.

In time of heavy rain evaporation from the cup ceases, water is absorbed from without, and mercury rises in tube *E*, simultaneously falling in tube *B*. Practically no water can enter the reservoir from the cup. Whether water flows from the cup through vial *D* to the outside is of no consequence.

The purpose of the second mercury valve is simply for use in filling a newly placed cup, as above described, since the cup and tubes cannot readily be inverted as with simpler absorbing mounting. As Harvey has suggested (*loc. cit.*), a stopcock might replace valve *D*, though experience with too frequently leaky cocks leads the writer to maintain that the mercury valve is as simple as, and far more certain than any possible cock. When the cup is to be removed it is simply lifted from its stopper and the contained water is allowed to escape at random. A new cup is placed on the stopper and suction is applied to tube *F* as at first.

To avoid possible disturbance of the valves and tubes at each reading, they being attached to a support, a large mouth bottle has been latterly employed, fitted with a tight and permanent waxed cork stopper. This stopper is perforated for the tube *E* and also bears a glass tube of large bore (about 1 cm.) and about 10 cm. long, reaching nearly through the cork from above. The lower surface of the cork is reamed away to form a broadly conical opening to conduct air bubbles upward into the large tube. This tube serves as does the small neck of the bottle in figure 5 and bears a file mark for the zero point. Still better, the large tube may be graduated in cubic centimeters, thus making the reading of small losses possible. The bottle is filled through this tube by use of a small funnel. This arrangement is shown in a diagram of the atmometer furnished by the writer, for publication by D. T. MacDougal.[22] The same arrangement is shown in Shive's diagram, about to be mentioned, which is here reproduced, with its author's kind permission, as figure 7.

Shive[23] has recently greatly improved the details of the nonabsorbing mounting so that no extra support is necessary and both mercury valves (as bulbed glass tubes) are brought to lie within the reservoir. The Shive arrangement seems practically perfect. It is shown in figure 8, which is self-explanatory. It is to be noted that the suction tube here projects to the outside, through the cork stopper, far enough for the attachment of a rubber tube. Only mercury enough to give a column about 3 cm.

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[22] MacDougal, D. T. The measure of environic factors and their biologic effects. Pop. Sci. Monthly **84**: 417-433, 1914. The diagram here mentioned is on page 421, and was unfortunately inverted by mistake. It represents a spherical porous cup.

[23] Shive, J. W.

in length in the undilated tube should be placed in the bulb of each valve.

The tests carried out by Harvey (*loc. cit.*) showed that it is easily possible to arrange the mercury valves so that a cup 30 cm. above the water level will need to absorb no more than about 0.01 cc. in order to stop water movement into the reservoir. With such an instrument, each time the valves are operated, as with the beginning of rain, 0.01 cc. of water is injected into the reservoir and when evaporation recommences this amount must be lost before the true record is taken up again. Thus, for every complete reversal of the valves a minus error is introduced amounting to only about 0.01 cc. This is quite negligible, and it must seldom happen that enough reversals occur in a period of operation to make the error considerable even in the aggregate.

Another error, also negligible, may be introduced by amounts of absorption too small to operate the valves. It may be supposed, for example, that a gentle shower, driven by wind, may wet one side of the cup so as to produce some absorption, while evaporation equalling or exceeding the amount of absorption may still be in progress on the leeward side. In such a case the final reading, or apparent loss for the period, would be less than the actual loss by the amount of water actually absorbed by the cup. If such conditions were long continued this kind of error might amount to more than that usually resulting from several complete reversals of the valves. For this difficulty no remedy can be suggested, other than that several cups as operated simultaneously on the same pair of valves and reservoir (to increase the actual rate of water loss) and that tubes of extremely small bore be employed in the valves. By this procedure the possible error may be reduced indefinitely.

The non-absorbing mounting should always be used for outdoor work; if observations are worth the trouble of making they should surely justify the slightly increased cost of operating this form of instrument. The futility of making records from the absorbing form, when operated in times of much rain, is well shown by the study carried out by Brown[24] in Jamaica.

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[24] Brown, W. H., Evaporation and plant habitats in Jamaica. Plant World **13**: 268–272, 1910.

*Height of Cups above Reservoir.* The influence exerted by the height of the water column above the porous cup, upon the rate of absorption during showers, is very pronounced unless the non-absorbing mounting is used, as has been shown, and an appreciation of this influence gives rise to the question what may be the relation of this height to the rate of evaporational water loss? This is an important matter, for the cups are operated at various levels and it is not always convenient for the reservoir to be immediately beneath. Furthermore, as evaporation proceeds and the water level in the reservoir is lowered, the height of the water column in question is of course increased. Especially is this true when a burette or other tall and slender container serves as reservoir.

The question here raised is important but its answer is simple; there is no appreciable relation between the rate of evaporation from a porous cup and the height of the water column below it. On theoretical grounds, the higher the cup above the reservoir the more concave should become the very small water-air menisci closing the pores of the wall. It should follow then that the vapor tension of these water surfaces must be decreased, and the rate of evaporation should also fall. The fact, however, is as above stated and the thinker is left, as frequently, to make hypotheses to explain it. It seems probable that the reason why no influence of the height of the water column is demonstrable is this: that the alteration induced in the films, and hence in the evaporation rate, by as great a change in column height as is ordinarily possible, is too small to be detected by ordinary methods.

It was first experimentally shown that variations in column height of upwards of a meter were quite without influence on the rate of water loss from the cup.[25] Afterwards variations of about two meters were tested, with the same result. But the most conclusive proof of the proposition before us was obtained by Mrs. Edith B. Shreve, working in the writer's laboratory, at Baltimore. Cups of the ordinary form were mounted on small-bore glass tubes about a meter in length, and the lower end of each tube was allowed to dip beneath the surface of mercury in

[25] Livingston, [illegible] 1906. Page 27

a suitable vessel. As evaporation went on mercury rose in the tube, following the receding water column. It is easily possible thus to obtain a mercury column over 60 cm. in height. It was conclusively shown that the rate of evaporation is not appreciably less with such a mercury column than it is with only the usual water column. Such being the case the question of the influence of height of cup above reservoir, as far as the operation of the atmometer is concerned, may be dismissed.

*The Influence of Air in the Cup.* If air bubbles enter the cup they must either remain there or pass out by dissolving and diffusing through the water of the cup wall. To remove such air, the cup is removed and refilled, in the case of the absorbing form; or strong and intermittent suction is applied to the lateral tube, with the non-absorbing form.

The most obvious effect produced by air in the cup is the variable error caused by the thermometer and barometer action of this air. It is to be remembered that such a body of gas is subjected to less than atmospheric pressure and that barometric and temperature changes in the surroundings will produce corresponding changes in the gas volume, much more pronounced changes than these similarly produced in the liquid. These changes, transmitted to the reservoir, are the sources of error here in view.

Another effect of air arises from the fact that such a mass of gas, lying at the top of the atmometer cup, prevents free contact of the porcelain wall with the internal water at that point. In so far as this occurs it is clear that the renewal of water in that part of the porous wall thus cut off from direct supply, must occur by lateral or longitudinal movement through the wall. Thus the portion of the porous porcelain which is on both sides in contact with gas must operate quite as does the disk or cylinder of the paper atmometer already discussed. This being the case, the same sort of difficulty is conceivable here as occurs with the paper form when the paper is large and the evaporation intense: that is, water may be removed from the outer surface of the air-protected portions of the porous wall at a rate faster than it can be supplied by capillary movement from adjacent, directly absorbing regions. Should this occur, it is clear that the nature of the evaporating surface would be profoundly altered, through changed water content of the porous porcelain at the affected place. Furthermore, if this drying-out of the cup wall proceeds far enough it may finally remove some portion of the water menisci which prevent the entrance of gaseous air, and the cup and tube must soon become emptied of water, all the unimbibed liquid escaping to the reservoir.

Whether any error in reading may arise from air in the cup depends upon the amount of air thus present and upon the atmospheric evaporating power at the time. With low evaporation rates longitudinal water movement through the affected part of the wall may suffice to keep it normally saturated. With a given rate of water loss there must be a limit of size to which, but not beyond which, the air mass in the cup may be increased. In the practical operation of the instrument, undissolved air should not be allowed to enter the cup. While small gas bubbles are undoubtedly harmless, yet it is the only safe procedure always to keep these as small as possible or entirely absent.

### *Operation of the Porous Cup Atmometer*

*Cleanliness.* The most important point to be remembered in the operation of porous cup atmometers is that they should be kept as clean and free from extraneous material as possible. This proposition leads, first to the use of nothing but good distilled water. With impure water trouble is sure to occur. In handling the cups they should never come in contact with the hands excepting on the shellacked or glazed portion.

If atmometers are to be operated near to the soil surface, the danger of injury from dust and from mud thrown upon the cups by rain is greatly increased. If the soil about the instrument is covered, as by stones or vegetation, this danger is largely avoided. To remove dust, insects, etc., frequent washing of the cup is advisable, rubbing it gently with a soft sponge and plenty of distilled water. In the case of shellacked cups the rubbing should be downward, to avoid transferring the slightly soluble shellac to the porous surface. With the glazed cups this cleaning may be more thorough. A tooth-brush serves very well for the latter but the softer cups are to be treated more carefully.

In moist situations moulds and algae frequently appear on the cups after a time. These may be removed by washing with strong alcohol and a sponge or cloth. As soon as a colony is detected, it should thus be destroyed, but great care should be exercised to prevent the alcohol touching the shellacked surface, shellac being readily soluble in alcohol; with cups having a glazed base no danger need be feared in this connection.

Since accidents of various kinds are not to be entirely avoided, it is well, where possible, to operate the instruments in duplicate or in triplicate, the cups being so placed as to have as nearly the same exposure as possible. Ordinarily the average of the two or three corrected readings is taken as the measure for the period, but a reading is discarded when it is obvious that some misfortune has befallen the corresponding cup.

Restandardization (see the next section) may be avoided by using two instruments exposed about a meter apart and replacing one of them at a time with an unused cup of known coefficient. The first one or two periods of operation after such replacement (if not too long) may be considered as restandardization periods for the cup longest in operation.

*Restandardization.* Even with all possible precautions, the coefficients of correction are apt to become altered through changes in the effective evaporating surface of the cup. It is therefore requisite that each cup be frequently restandardized. By this means changes in the magnitude of the coefficient may be detected and allowed for. It has usually been found adequate to restandardize each cup after from two to four weeks of operation in the open. Since it requires some time for this restandardization, the record is kept continuous by replacing the cup which is to be restandardized by another standardized cup. During the following period of from two to four weeks the first cup is restandardized and is ready to return to operation when the second comes away.

It is to be borne in mind that the purpose of the restandardization is to determine the coefficient of correction of the cup *at* *the time when it ceased operating.* It is therefore very essential that the evaporating surface be not allowed to alter between the time when the cup is removed from operation and that at which it is restandardized. Cups to be restandardized should be dried, carefully wrapped in clean paper, and stored in a dry place until they can be restandardized.

If restandardization is to be attempted by the user of the instrument, it is absolutely essential that there be at hand a cup of known coefficient, of the same form as those to be restandardized. This cup must never have been used since it came from its own standardization, having been kept dry and properly wrapped meanwhile. All other methods of standardization, excepting by means of such a cup, have proved unsatisfactory. If possible, the restandardization should be performed by means of a rotating table, preferably indoors with an electric fan to increase the rate of evaporation. The operation is the same as that already described. After restandardization the cups are air dried before being wrapped for preservation.

Where a rotating table is not available, the cups may be standardized by placing them (with the cup of known coefficient) in the open, in a place where all will receive equal exposure to sun and wind and where they will be as free from dust as possible. Rain falling upon them vitiates the results, and may alter cups which have easily removable material adhering to the outer surface. It is best not to allow rain to fall upon the cups during standardization.

Cups may also be standardized indoors, though not satisfactorily, by arranging them about 50 cm. apart in each direction, in a room which receives no direct sunshine and in which the air conditions are as nearly equable as possible. The group of instruments should be in the center of the room, not in the vicinity of furniture or other objects, and the room is to be kept closed to avoid drafts. A small group may be placed near the center of a large table, but it is not desirable to have any cups near vertical air currents such as occur about the margin of a table; it is better to place the instruments on the floor. No preventable air movement is to be allowed; it would surely affect the different cups unequally. It is far better to employ a rotating table which insures the same treatment to all cups of the group and avoids, at a single stroke, most of the difficulties of atmospheric conditions.

In restandardizing, the cups are operated for one period (10 to 48 hours, according to amount of water loss, which should be great enough to read with small percentage of error, say 25 cc. as a minimum loss), and the respective coefficients are calculated as already described. The reading of the cup of known coefficient is multiplied by its coefficient, and the resulting standard reading is then divided by the actual reading of the cup to be standardized. The quotient is the required coefficient of the last-named cup. If these agree (within 0.04 and 0.05) with the corresponding original coefficients, the operation of the cups is discontinued, and they are dried and wrapped, being now given the newly determined coefficient. If the new coefficient does not thus nearly agree with the old, the operation is continued for a second period. If, now, the second new coefficients agree with the first new coefficients (within 0.04 or 0.05), the average of the two new coefficients is taken as the new coefficient to be used. If agreement for any cup is not satisfactory, the operation is continued until a satisfactory average new coefficient is obtained, or until the cup proves itself incapable of restandardization, by showing continued fluctuations in the coefficient value. Four or five periods, at the most, should always suffice.

*Renovation.* Cups that prove incapable of restandardization or appear too much soiled for further use, and those which have developed a coefficient which is greater than 0.80 or less than 0.60 (for 8 cm. cups) and have therefore become suspicious, should be renovated or discarded. Cups may usually be brought back to a condition as satisfactory as that of new ones, by carefully scraping the whole of the porous surface with freshly broken glass and then smoothing by means of sandpaper. After this treatment they usually give perfectly satisfactory non-fluctuating coefficients, somewhat different, however from the corresponding original ones. The insoluble cups cannot be so treated, but they may be heated to a glowing condition to remove organic matter, and then washed with acid, etc., to remove salts.

*Records and the Correction of Readings.* Atmometer records should be kept in such a way that the cup number and the original coefficient are always available with the record of readings. After restandardization the proper coefficient for each period of operation is inserted and the requisite correction is made in each case. If, after operation, a cup exhibits no marked change (not over 0.03 or 0.04,) in its coefficient, the average of the original and new coefficients (the latter from restandardization) is taken as the coefficient for the correction of all readings obtained from that cup between the two standardizations. If, however, the coefficient has changed appreciably during operation, the various readings are each corrected by means of a corresponding coefficient interpolated between the original and the new one. If a cup shows itself incapable of restandardization, the later readings cannot be corrected and are useless, though the readings of the first week (or thereabouts) of its operation may probably be corrected by means of the original coefficient.

An example of the interpolation of coefficients follows: Suppose the original coefficient were 0.75 and the new coefficient were 0.90, and suppose that the cup operated four weeks and w[illegible] read weekly. Let the series of weekly readings be $a$, $b$, $c$, and [illegible] It may be assumed that the original coefficient held for the firs[illegible] week and that the coefficient gradually and uniformly altered during the remainder of the time. Now, $0.90 - 0.75 = 0.15$, the amount of change in three weeks, from which we deduce that the coefficients to be used for correcting the readings $a$, $b$, $c$, and $d$ are approximately 0.75, 0.80, 0.85, and 0.90, and the corrected readings become $0.75a$, $0.80b$, $0.85c$, and $0.90d$. This method possesses far lower probability of error, in such a case than would the method by which the mean of 0.75 and 0.90 (0.825) is applied throughout the series. When instruments are operated in duplicate or in triplicate, there is usually available more or less definite evidence as to whether a change in one of the cups was gradual or rapid, etc.

*The Interpretation of Atmometer Readings.* From what has been said in the preceding discussions it appears that the thing aimed at in atmometric studies is a measure of the power of the air surrounding the instrument to remove water vapor from a specified surface exposed in a specified way. Evaporation data cannot be interpreted, then, excepting in terms of the particular form, size, etc., of instrument that is used.

This feature has given rise to considerable misunderstanding in regard to the various instruments and the value of their readings. It has frequently been thought, for example, that several porous cup atmometers operated at different places show the comparative rates of transpiration of plants growing in the vicinity of the respective instruments. While this conclusion may sometimes be approximately true, it does not *necessarily* follow at all. In order that this may be true it would be necessary that the plants expose surfaces for evaporation having always the same properties as the surfaces of the instruments, and that instruments and plants be similarly exposed. As a matter of fact, we know that plant surfaces are continually altering in their transpiring power[26] and that they are not the same from hour to hour and from day to day. Since the atmometer surface remains constantly of the same water-supplying power (if this is not approximately true or cannot be assumed after the corrections have been made, it is useless as an atmometer), it is clear enough that actual plant transpiration cannot be calculated from atmometric data alone.

On the other hand, the exposure, surface, etc., of the porous cup atmometer are so nearly similar to the corresponding features of plants *in general*, that the instrument offers the only means so far available for studying *the evaporating power of the air* as it generally affects the rate of plant transpiration. Atmometers are employed in this connection to measure an *environmental condition* and their readings are indices of the power of the air

Livingston, B. E., and Brown, W. H., Relation of the daily march of transpiration to variations in the water content of foliage leaves. Bot. Gaz. **53**: 309-330, 1912.

Livingston, *loc. cit.*, 1906.

—— The resistance offered by leaves to transpirational water loss. Plant World **16**: 1-35, 1913.

Bakke, A. L., Studies on the transpiring power of plants as indicated by the method of standardized hygrometric paper. Jour. Ecol. **2**: 145-173, 1913.

to do work in promoting the vaporization of water from the *atmometer surface*. In so far as the surface exposed by the instrument is like that exposed by plants, and in so far as the exposure is the same in the two cases, the readings are indices of the power of the air to remove water from unchanging plant surfaces. From the work that has so far been done in this new line of study, it appears that the porous cup instrument does, indeed, rather closely approximate the exposure, etc., of plants in general, so that the atmospheric evaporating powers to which plants in different habitats or at different times are exposed can be approximately measured and compared by this means. No doubt special problems will require special forms of atmometer, as has been indicated.

(*To be continued.*)

# THE FLORA OF THE WILLIAMS DIVISION OF THE TUSAYAN NATIONAL FOREST, ARIZONA

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The Tusayan National Forest lies on the extreme edge of the Colorado Plateau in northern Arizona, west of Flagstaff and south of the Grand Cañon. The lowest portion of the Forest is about 5000 feet in elevation, lying just below the edge of the Plateau, and the highest portions are the summits of Bill Williams, Sitgreaves and Kendrick Peaks, which rise to the vicinity of 10,000 feet. The major portion of the Forest is comprised in the rolling surface of the Plateau, lying between 6500 and 8000 feet. By reason of its diversity of topography and range of elevations the Tusayan Forest comprises four life zones, the Upper Sonoran, Transition, Canadian, and Hudsonian.

## UPPER SONORAN

This zone occurs at elevations of 5000 to 7000 feet and contains three main types: woodland, the tree species of which consist almost entirely of piñon (*Pinus edulis*) and juniper (*Juniperus monosperma*), brush areas covered chiefly with shin oak (*Quercus grisea*), and parks or treeless areas supporting grasses and weeds.

Probably 50% of the herbaceous vegetation in this zone is blue grama (*Bouteloua oligostachya*). Some sideoats grama (*B. curtipendula*) grows on the rocky south slopes. A three-awn grass, *Aristida arizonica*, is quite noticeable because of its long reddish purple awns or beards. Snakeweed (*Gutierrezia* spp.), rabbit bush (*Chrysothamnus* spp.) and pingue (*Hymenoxys floribunda*) are abundant, growing usually in pure stands in the open where they cover many acres to the exclusion of other species. Snakeweed and rabbit bush are worthless, being un-palatable to stock. Pingue is poisonous to sheep but luckily they do not eat it when other forage can be obtained.

The brush areas are found at the lower altitudes, along the Mogollon Rim, often growing in dense clumps with a few scattering grasses and weeds underneath them. Shin oak (*Quercus grisea*), manzanita (*Arctostaphylos pungens*), Apache plume (*Fallugia paradoxa*), skunk bush (*Rhus trilobata*), *Ceanothus greggii* and *Eriogonum* spp. are the most common shrubs. Since most of the shrub or "browse" species are palatable to stock these areas are highly esteemed by stockmen.

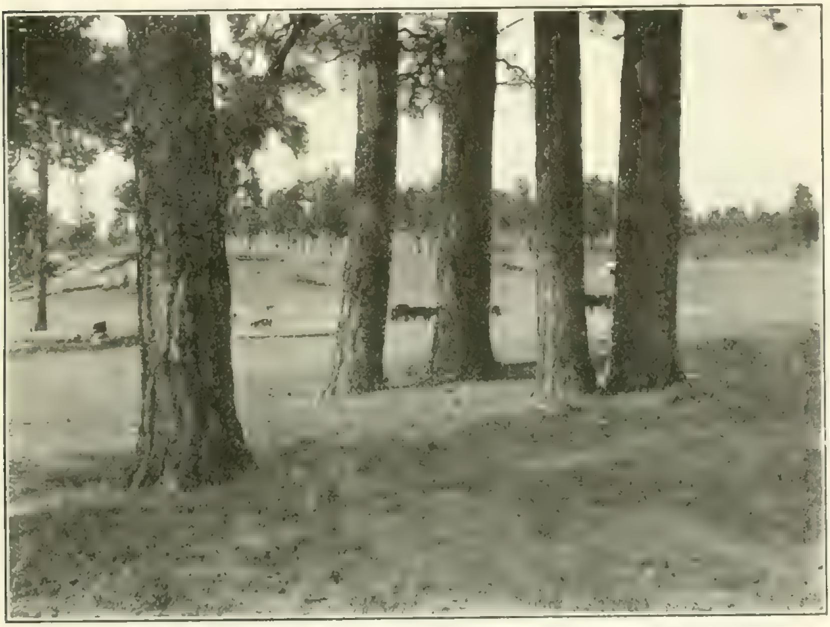

Fig. 1. Transition Zone. An open stand of mature *Pinus ponderosa*.

The line of demarcation between the woodland and park types is often indefinite because of the scattering growth of woodland trees. The herbaceous species common to the woodland are found in the parks.

The minor characteristic species of the Upper Sonoran zone are *Agropyron smithii*, *Muhlenbergia wrightii*, *Koeleria cristata*, *Sitanion pubiflorum*, *Gymnolomia multiflora*, *Psoralea tenuiflora*, *Helianthus lenticularis*, *Opuntia* spp., *Stachys* sp., *Tetradymia canescens*, and numerous species of *Aster*.

## TRANSITION ZONE

For all practical purposes this zone may be considered as coincident with the yellow pine (*Pinus ponderosa*) type of forest. Having an elevation of 7000 to 8500 feet, with many springs and seeps scattered through it, and a rainfall of 15 to 25 inches, none of the desert plants appear.

The predominating trees are yellow pine with some red fir (*Pseudotsuga taxifolia*) and balsam (*Abies concolor*) on the higher north slopes. Considerable Gambel oak (*Quercus gambelii*) grows under the pines while on many of the north slopes there is a dense understory of locust (*Robinia neo-mexicana*). Scattering willows (*Salix* spp.) occur along the streams. Mountain bunch grass (*Festuca arizonica*), pine grass (*Muhlenbergia gracilis*), and beardless pine grass (*Blepharineuron tricholepis*) are the most common grasses. Lupine (*Lupinus hillii*), and species of *Geranium*, *Potentilla*, and *Castilleja* are noticeable weeds. One of the most poisonous of the loco weeds—rattle pod (*Aragallus lambertii*)—is found here growing generally on north slopes. Other characteristic species are *Festuca arizonica*, *Andropogan scoparius*, *Bouteloua oligostachya*, *Epicampes rigens*, *Sitanion* spp., *Sporobolus interruptus*, and *S. confusus*, *Aristida arizonica*, *Calochortus gunnisonii*, *Erythrocoma arizonica*, *Vicia* spp., *Monarda stricta*, *Ceanothus fendleri*, *Symphoricarpos oreophilus*, *Aster* spp., *Erigeron* spp., *Iris missouriensis*, *Senecio* spp., and *Tithymalus montanus*.

## CANADIAN ZONE

The Canadian Zone lies on the upper slopes of Bill Williams, Sitgreaves and Kendrick Mountains which are 9000 to 10,000 feet above sea level. Red fir (*Pseudotsuga taxifolia*), balsam (*Abies concolor*), spruce (*Picea engelmanni*), aspen (*Populus tremuloides*), and white pine (*Pinus flexilis*) are the principal trees. On some of the north slopes the spruce grows so densely as to exclude almost all other vegetation. Reproduction of all tree species is very thick throughout the entire zone. Because of the dense shade here there is less grass than in the lower zones; both in species and quantity. An exception is found on the bald knolls and in the few small parks where bunch grass (*Festuca arizonica*) grows luxuriantly. Several species of bromus grow well here. *Poa* spp., *Melica parviflora*, *Festuca*

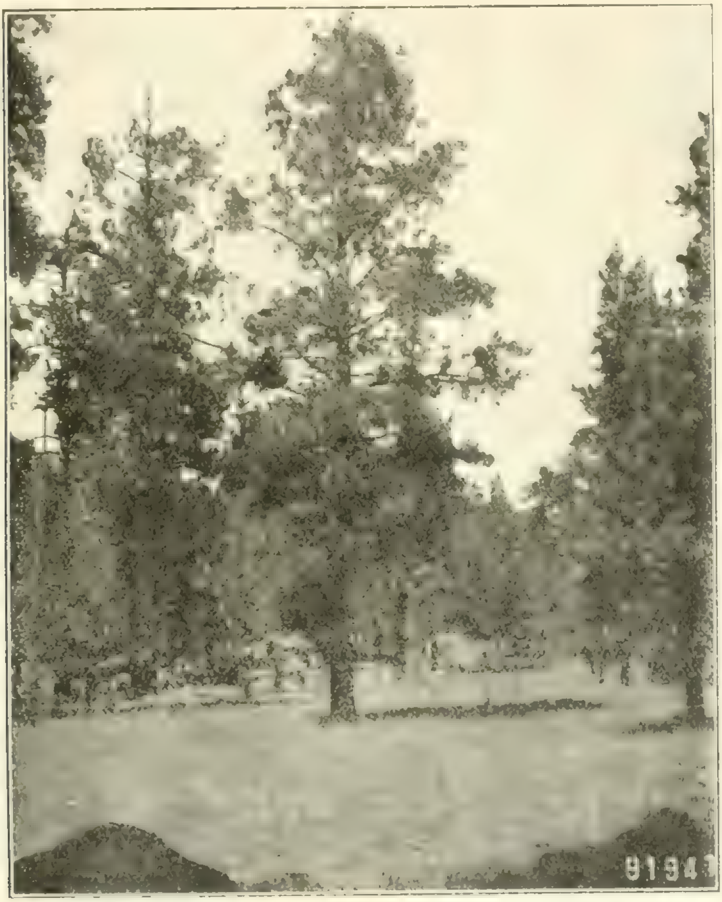

Fig. 2. Transition Zone. A heavy stand of *Aristida arizonica* in the foreground under *Pinus ponderosa.*

*orina pseudorina*, *Grossularia pinetorum*, *Cedronella mexicana*, and *Sorbus dumosa*, are also seen here, growing scatteringly.

## HUDSONIAN ZONE

A small area at the top of Kendrick Mountain, elevation 10,000 feet is the only example of this zone on the Tusayan Forest. The tree species are spruce (*Picea engelmanni* and cork bark fir (*Abies arizonica*). A large amount of pipsissewa (*Chimaphila umbellata*) and some of the Canadian zone species grow here.

Following is a check list of some of the species growing in this part of the Tusayan Forest. Although it is only a partial list it is thought that most of the species growing there are enumerated.

Most of the shrubby and herbaceous plants were identified at the National Herbarium at Washington, D. C. The nomenclature of the "Manual of Rocky Mountain Botany" by Coulter and Nelson is used wherever possible for shrubs and herbaceous plants; Sargent's "Manual of the Trees of North America" is followed in naming the trees.

| | |
|---|---|
| Polypodiaceae | |
| *Pteridium aquilinum* var. *pubescens* Underw. | Brake |
| Pinaceae | |
| *Pinus ponderosa* Laws. | Yellow pine |
| *Pinus flexilis* James | Limber pine |
| *Pinus edulis* Engelm. | Piñon |
| *Picea engelmanni* (Parry) Engelm. | Englemann spruce |
| *Abies concolor* (Gord.) Parry | Balsam, White fir |
| *Abies arizonica* Merriam | Cork bark fir |
| *Pseudotsuga taxifolia* (Lam.) Britton | Red fir |
| *Cupressus arizonica* Greene | Cypress, Yew |
| *Juniperus pachyphloea* Torr. | Alligator bark juniper |
| *Juniperus monosperma* (Engelm.) Sarg. | One-seed juniper |
| *Juniperus scopulorum* Sarg. | Cedar |
| *Juniperus communis* L. | Ground hemlock |
| Gnetaceae | |
| *Ephredra antisyphilitica* S. Wats. | Mormon tea |
| Gramineae | |
| *Andropogon scoparius* Michx. | Small feather grass |
| *Sorghastrum nutans* (L.) Nash | |

| | |
|---|---|
| *Hilaria jamesii* (Torr.) Benth. | Galleta |
| *Hilaria cenchroides* H. B. K. | Curly mesquite |
| *Echinochloa crus-galli* (L.) Beauv. | Slough grass |
| *Panicum virgatum* L. | Switch grass |
| *Panicum obtusum* H. B. K. | Vine mesquite |
| *Panicum bulbosum* H. B. K. | |
| *Panicum barbipulvinatum* Nash | Fuzzy six-weeks grass |
| **Chaetochloa viridis* Scribn.[1] | Foxtail |
| *Aristida fendleriana* Steud. | Small three-lawn grass |
| *Aristida arizonica* Vasey | Curly three-lawn grass |
| *Stipa pringlei* Scribn. | |
| *Stipa tweedyi* Scribn. | Needle grass |
| *Oryzopsis micrantha* (T. & R.) Thurber | Mountain rice |
| *Muhlenbergia pauciflora* Vasey | |
| *Muhlenbergia gracilis* Trin. | Pine grass |
| *Muhlenbergia vaseyana* Scribn. | Broadleaf bunch grass |
| *Muhlenbergia wrightii* Vasey | Wild timothy |
| *Muhlenbergia gracillima* Torr. | Hair grass |
| *Muhlenbergia squarrosa* (Trin.) Rydb. | Squaw grass, Salt grass |
| *Epicampes rigens* Benth. | Deer grass |
| *Alopecurus geniculatus* L. | Swamp timothy |
| *Alopecurus fulvus* J. E. Smith | False timothy |
| *Sporobolus confusus* (Fourn.) Vasey | Six-weeks grass |
| *Sporobolus interruptus* Vasey | Black sporobolus |
| *Sporobolus cryptandrus* (Torr.) Gray | Sacaton |
| *Blepharineuron tricholepis* (Torr.) Nash | Beardless pine grass |
| *Polypogon monspeliensis* (L.) Desf. | Beard grass |
| *Agrostis hiemalis* (Walt.) B. S. P. | Tickle grass |
| *Agrostis exarata* Coult. | Swamp tickle grass |
| *Agrostis alba* L. | Red top |
| *Schedonnardus paniculatus* (Nutt.) Trel. | Crab grass |
| *Bouteloua eriopoda* Torr. | Wooly foot grama |
| *Bouteloua oligostachya* (Nutt.) Torr. | Blue grama |
| *Bouteloua prostrata* Late grama. | Prostrate grama |
| *Bouteloua curtipendula* (Michx.) Torr. | Side oats grama |
| *Koeleria cristata* (L.) Pers. | June grass |
| *Melica parviflora* (Porter) Scribn. | |
| **Poa pratensis* L. | Kentucky blue grass |
| *Poa fendleriana* (Steud.) Vasey | Blue grass |
| *Glyceria borealis* (Nash) A. Nels. | Manna grass |
| *Festuca octoflora hirtella* Piper | Annual festuca |
| *Festuca ovina pseudovina* Hack. | Sheep's fescue |
| *Festuca arizonica* Vasey | Mountain bunch grass |
| *Bromus subvelutinus* Shear | Bromus, Wild oats |
| *Bromus porteri* (Coult.) Nash | Bromus, Wild oats |
| *Bromus richardsonii* Link. | Bromus, Wild oats |

[1] Species indicated by * are introduced.

| | |
|---|---|
| *Agropyron smithii* Rydb. | Bluestem |
| *Agropyron pseudorepens* S. & S. | Bluestem |
| *Agropyron tenerum* Vasey | Swamp bluestem |
| *Hordeum pusillum* Nutt. | Dwarf barley |
| *Hordeum jubatum* L. | Wild barley |
| *Sitanion longifolium* J. G. Smith | |
| *Sitanion glabrum* J. G. Smith | |
| *Sitanion molle* J. G. Smith | |
| CYPERACEAE | |
| *Cyperus fendlerianus* Boeckl. | Pine sedge, Nut grass |
| *Eleocharis palustris* (L.) R. & S. | Spike sedge |
| *Carex vulpinoidea* Michx. | Sedge |
| *Carex* sp. | Sedge |
| JUNCACEAE | |
| *Juncus interior* Wieg. | Rush |
| *Juncus mexicanus* Willd. | Wire grass |
| *Juncus* sp. | Rush |
| LILIACEAE | |
| *Allium neomexicanum* Rydb. | Wild onion |
| *Calochortus gunnisonii* S. Wats. | Mariposa lily |
| *Yucca radiosa* (Engelm.) Trel. ? | Soapweed, Amole |
| *Yucca* sp. | Yucca |
| *Nolina microcarpa* S. Wats. | Bear grass |
| AMARYLLIDACEAE | |
| *Agave utahensis* Engelm. ? | Mescal, Agave, Century plant |
| IRIDACEAE | |
| *Iris missouriensis* Nutt. | Iris, Flag |
| *Hesperanthus torreyi* S. Wats. | Yellow lily |
| JUGLANDACEAE | |
| *Juglans rupestris* Engelm. | Walnut |
| SALICACEAE | |
| *Populus tremuloides* Michx. | Aspen |
| *Populus angustifolia* James | Willow leaf cottonwood |
| *Salix* sp. | Mountain willow |
| FAGACEAE | |
| *Quercus gambelii* Nutt. | Gambel oak |
| *Quercus grisea* Lieb. | Shin oak |
| *Quercus reticulata* H. K. B. | Live oak |
| ULMACEAE | |
| *Celtis mississippiensis* var. *reticulata* (Torr.) Sarg. | Hackberry |
| MORACEAE | |
| *Morus celtidifolia* H. B. K. | Mulberry |
| LORANTHACEAE | |
| *Razoumofskya camphylopoda* (Engelm.) Piper | False mistletoe |
| *Phoradendron villosum* Nutt. | Mistletoe |

| | |
|---|---|
| POLYGONACEAE | |
| *Eriogonum racemosum* Nutt. | |
| *Eriogonum alatum* Torr. | |
| *Eriogonum pharnaceoides* Torr. | |
| †*Eriogonum* sp.[2] | |
| *Eriogonum* sp. | |
| **Rumex cripsus* L. | Curled dock |
| CHENOPODIACEAE | |
| *Chenopodium fremontii* S. Wats. | Lamb's quarter |
| *Atriplex canescens* James | Wafer sage, Chemise |
| *Eurotia lanata* (Pursh) Moq. | Feather sage |
| **Salsola kali* L. | Russian thistle |
| AMARANTHACEAE | |
| *Amaranthus palmeri* A. Wats. | Pigweed |
| PORTULACACEAE | |
| †*Talinum validulum* Greene. | |
| *Portulaca* sp. | Purslane |
| CARYOPHYLLACEAE | |
| *Arenaria fendleri* A. Gray | Sandwort |
| RANUNCULACEAE | |
| *Aquilegia chrysantha* A. Gray | Columbine |
| *Delphinium scaposum* Greene | Larkspur |
| *Thalictrum wrightii* A. Gray ? | Meadow rue |
| BERBERIDACEAE | |
| *Berberis nana* Greene | Oregon grape |
| *Berberis fremontii* Torr. | Algerita, Palo amarillo |
| CRUCIFERAE | |
| *Lepidium montanum* Nutt. | Pepper grass |
| *Sophia brevipes* (Nutt.) Rydb. | Tansy mustard |
| CAPPARIDACEAE | |
| *Cleome serrulata* Pursh | Rocky Mountain bee plant |
| GROSSULARIACEAE | |
| *Ribes mescalerium* Cov. | Gooseberry |
| *Ribes* sp. | Currant |
| *Grossularia pinetorum* (Greene) Cov. & Brit. | Spiny gooseberry |
| PLANTANACEAE | |
| *Platanus wrightii* S. Wats. | Sycamore |
| HYDRANGEACEAE | |
| *Fendlera rupicola* A. Gray | |
| ROSACEAE | |
| *Cercocarpus parvifolius* Nutt. | Mountain mahogany |
| *Cowania mexicana* D. Don | Quinine bush |
| *Holodiscus* sp. | |
| *Spiraea microphylla* Rydb. | Meadow sweet |
| *Petrophyton caespitosum* (Nutt.) Rydb. | |

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[2] Species indicated by † were reported by the National Herbarium as new to science.

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|---|---|
| *Chamaebatiaria millefolium* (Torr.) Maxim. | |
| *Fallugia paradoxa* (Don) Endl. | Apache plume |
| *Bosskia neomexicana* (A. Gray) Rydb. | False raspberry |
| *Fragaria americana* (Porter) Brit. | Wild strawberry |
| *Potentilla monspeliensis* L. | |
| *Potentilla thurberi* A. Gray | Red cinquefoil |
| *Potentilla crinita* A. Gray | Silver weed |
| *Erythrocoma arizonica* Greene. | Alum root |
| *Rosa fendleri* Crepin | Wild rose |
| POMACEAE | |
| *Amelanchier alnifolia* Nutt. | Service berry |
| *Sorbus dumosa* Greene | Elderleaf mountain-ash |
| DRUPACEAE | |
| *Prunus crenulata* ? | Wild cherry |
| LEGUMINOSAE | |
| *Calliandra humilis* Benth. | Ground acacia |
| *Thermopsis divaricarpa* A. Nels. | Yellow pea |
| *Sophora serica* Nutt. | False loco |
| *Lupinus sileri* S. Wats. | Dwarf lupine |
| *Lupinus hillii* Greene | Lupine |
| *Lotus wrightii* A. Gray | Trefoil, Red and yellow pea |
| **Melilotus alba* Desv. | Sweet clover |
| *Trifolium rusbyi* Greene | White clover |
| *Trifolium fendleri* Greene | Clover |
| *Robinia neomexicana* A. Gray | Locust |
| *Astragalus bigelovii* A. Gray | Wooly loco |
| *Astragalus greeni* A. Gray | |
| *Astragalus hosackiae* Greene | Prostrate loco |
| *Aragallus lambertii* (Pursh) Greene | Rattlepod loco |
| †*Amorpha* sp. | Spice bush |
| *Amorpha* sp. | |
| *Psoralea tenuiflora* Pursh | Indian bread root |
| *Parosela albiflora* (A. Gray) Vail | |
| *Petalostemon oligophyllus* (Torr.) Rydb. | Prairie clover |
| *Vicia perangusta* Greene | Vetch |
| *Lathyrus arizonicus* Britton | Peavine |
| *Cologania longifolia* A. Gray | Pea |
| GERANIACEAE | |
| *Geranium caespitosum* James | Big filaree |
| *Geranium gracilentum* Greene | White geranium |
| **Erodium cicutarium* (L.) L'Her. | Alfilaria, Filaree |
| OXALIDACEAE | |
| *Oxalis stricta* L. | Yellow wood sorrel |
| LINACEAE | |
| *Linum lewisii* Pursh | Blue flax |
| *Linum berlandieri* Hook. | Yellow flax |
| RUTACEAE | |
| *Ptelea* sp. | Wafer ash |

| | |
|---|---|
| EUPHORBIACEAE | |
| *Tragia ramosa* Torr. | Noseburn |
| *Euphorbia montana* Engelm. | Spurge |
| *Euphorbia fendleri* T. & G. | Ground milkweed |
| ANACARDIACEAE | |
| *Rhus elegantula* Greene | Sumac |
| *Rhus rydbergii* Small | Poison ivy |
| *Rhus trilobata* Nutt. | Skunk bush, Lemonade berry |
| ACERACEAE | |
| *Acer glabrum* Torr. ? | Dwarf maple |
| *Acer negundo* L. | Boxelder |
| SAPINDACEAE | |
| *Sapindus drummondii* H. & A. | Soap berry |
| *Forsellesia spinescens* Greene | |
| RHAMNACEAE | |
| †*Rhamnus platyphylla* Greene | False holly |
| †*Rhamnus* sp. | |
| *Ceanothus fendleri* A. Gray | |
| *Ceanothus greggii* A. Gray | |
| VITACEAE | |
| *Vitis arizonica* Engelm. | Wild grape |
| MALVACEAE | |
| *Sidalcea neomexicana* A. Gray | Purple mallow |
| *Sphaeralcea emoryi* Torr. | Globe mallow |
| HYPERICACEAE | |
| *Hypericum formosum* H. B. K. | St. John's wort |
| VIOLACEAE | |
| *Viola mariculata* Greene | Violet |
| CACTACEAE | |
| *Opuntia* sp. | Prickly pear |
| *Opuntia* sp. | Cholla |
| *Opuntia* sp. | |
| ONAGRACEAE | |
| *Onagra hookeri* (T. & G.) Small | Evening primrose |
| *Gaura suffulta* Engelm. | |
| UMBELLIFERAE | |
| *Pseudocymopterus montanus* (A. Gray) C. & R. | |
| *Pseudocymopterus purpureus* (C. & R.) Rydb. | |
| *Eulophus* sp. | |
| CORNACEAE | |
| *Cornus stolonifera* Michx. | Dogwood |
| *Garrya flavescens* S. Wats. ? | |
| PYROLACEAE | |
| *Chimaphila umbellata* (L.) Nutt. | Princess pine, Pipsissewa |
| MONOTROPACEAE | |
| *Pterospora andromedea* Nutt. | Pine drops |
| ERICACEAE | |
| *Arctostaphylos pungens* H. B. K. | Manzanita |

| | |
|---|---|
| OLEACEAE | |
| *Fraxinus toumeyi* Britton | Toumey ash |
| *Adelia neomexicana* (A. Gray) Kze. | False privet, Palo blanco |
| *Menodora scabra* A. Gray | Twin berry |
| GENTIANACEAE | |
| *Gentiana elegans* A. Nels. ? | Purple gentian |
| *Frasera scabra* (Jones) Rybd. | Skunk cabbage |
| ASCLEPIADACEAE | |
| *Asclepias* sp. | Slender leaf milkweed |
| *Asclepias involucrata* Engelm. | Dwarf milkweed |
| *Asclepias speciosa* Torr. | Milkweed |
| *Asclepiodora decumbens* (Nutt.) A. Gray | Milkweed |
| POLEMONIACEAE | |
| *Phlox woodhousii* A. Gray | Phlox |
| *Gilia arizonica* Greene | |
| BORAGINACEAE | |
| *Lappula* sp. | Beggar lice |
| *Lithospermum multiflorum* Torr. | Puccoon |
| LABIATAE | |
| †*Mentha* sp. | Mint |
| **Marrubium vulgare* L. | Hoarhound |
| *Cedronella mexicana* Benth. | Mountain hyssop |
| *Dracocephalum parviflorum* Nutt. | Dragon head |
| *Monardella* sp. | Pennyroyal |
| †*Stachys* sp. | Adobe weed |
| *Monarda stricta* Wooton | Horse mint |
| *Hedeoma* sp. | False pennyroyal |
| SOLANCEAE | |
| *Solanum triflorum* Nutt. ? | Wild tomato |
| *Lycium pallidum* Miers | |
| *Datura meteloides* DC. | Jimson weed |
| SCROPHULARIACEAE | |
| **Verbascum thapsus* L. | Mullein |
| *Pentstemon linarioides* A. Gray | |
| *Pentstemon torreyi* Benth. | |
| *Pentstemon* sp. | |
| *Mimulus langsdorfii* Sims. | Monkey flower |
| *Castilleja* sp. | Indian paint brush |
| †*Castilleja* sp. | Indian paint brush |
| *Orthocarpus luteus* Nutt. | |
| *Cordylanthus wrightii* A. Gray | Plume weed |
| PLANTAGINACEAE | |
| *Plantago purshii* R. & S. | Indian wheat |
| RUBIACEAE | |
| *Houstonia wrightii* A. Gray | Ground lilac |
| CAPRIFOLIACEAE | |
| *Sambucus melanocarpa* A. Gray | Elder berry |
| *Symphoricarpos oreophilus* A. Gray | Wax berry, Snow berry |

COMPOSITAE

| | |
|---|---|
| *Brickellia grandiflora* Nutt. | Coleosanthus |
| *Brickellia wrightii* A. Gray | Coleosanthus |
| *Gutierrezia tenuis* Greene | Snake weed, oil weed |
| *Grindelia oxylepis* Greene | Gum weed |
| *Chrysothamnus pulchellus* (A. Gray) Greene | Rabbit bush |
| †*Chrysothamnus* sp. | Rabbit bush |
| *Sideranthus gracilis* (Nutt.) Rydb. | |
| *Solidago marshallii* Rothr. | Golden rod |
| *Solidago arizonica* (A. Gray) Wooton & Standley | Golden rod |
| *Aster commutatus* A. Gray | White prairie aster |
| †*Aster* sp. | Blue aster |
| *Machaeranthera linearis* Greene | Blue daisy |
| *Leucelene ericoides* (Torr.) Greene | False heather |
| *Erigeron eximius* Greene | Daisy |
| *Erigeron divergens* T. & G. | Daisy |
| †*Erigeron gummosus* Greene | Daisy |
| *Antennaria rosulata* Rydb. | Ladies' tobacco |
| *Gnaphalium wrightii* A. Gray | Cud weed |
| *Ambrosia psilostachya* DC. | Rag weed |
| *Gymnolomia multiflora* (Nutt.) B. & H. | Turpentine weed, Resin weed |
| *Helianthus lenticularis* Dougl. | Sunflower |
| *Helianthus ciliaris* DC. | Dwarf sunflower |
| *Helianthella arizonica* (A. Gray) | Wood sunflower |
| *Coreopsis tinctoria* Nutt. | Tick seed |
| *Psilostrophe tagetina* (Nutt.) Greene | Quinine weed |
| *Pericome caudata* A. Gray | Wing weed |
| *Hymenopappus luteus* Nutt. | White leaf ragweed |
| *Bahia dissecta* (A. Gray) Britton | Yellow ragweed |
| *Hymenothrix wrightii* A. Gray | |
| *Actinella bigelovia* A. Gray | |
| *Hymenoxys floribunda* (A. Gray) Cockrl. | Pingue, Rubber weed |
| *Tagetes micrantha* Cav. | Licorice weed |
| *Achillea millefolium* L. | Yarrow |
| *Artemisia wrightii coloradensis* (Osterh.) A. Nels. | Sage |
| *Artemisia forwoodii* S. Wats. | Red stemmed sage |
| *Artemisia ludoviciana* Nutt. | Slender sage |
| *Artemisia frigida* Willd. | Estafieta, Sweet sage |
| *Tetradymia canescens* DC. | Black sage |
| *Senecio fendleri* A. Gray | |
| *Senecio filifolius* Nutt. | |
| *Senecio longilobus* Benth. | Butter weed, False pingue |
| *Carduus undulatus* Nutt. | Thistle |
| *Carduus ochrocentrus* (A. Gray) Greene | Thistle |
| *Hieracium fendleri* Schultz Bip. | Wooly weed |
| **Lactuca scariola* L. | Wild lettuce |
| *Troximon arizonicum* Greene | Dandelion |

## BOOKS AND CURRENT LITERATURE

METHODS IN PHYSIOLOGY OF NUTRITION.—As the title of this book[1] indicates it deals exclusively with those aspects of plant physiology more directly related to nutrition, and is more especially concerned in presenting the methods of the chemist. More than ever, one infers from a reading of the captions, does the trend of modern plant physiology direct itself toward the domain of chemistry. The book, the author hopes, occupies a position intermediate between biochemical books on the one hand and those dealing in the more usual way with plant physiology. As the tendency for the biochemist is less strong toward physiology than is salutary, any influence to bring him to make use of the point of view of the physiologist is to be properly appreciated. To this end the author has made use of a physiological classification of his material and has displayed the chemical methods, which constitute the bulk of the text, under the appropriate physiological headings. One must not think however only of *in vitro* chemistry, in a narrow sense. For example, the botanist as chemist must not only determine the composition of mixed gases, but he must set up an experiment with the living plant in order to get the gases for determination. Grafe has made a large effort to bring together all these coördinate methods, and the amount delivered to the botanical constituency is really quite great—494 pages and roughly 230,000 words—thoroughly enough done to be of a good deal of value. The author's claim to have treated all the material he presents, critically upon the basis, with few exceptions, of tests in his own laboratory, is a very large one, and the reviewer, for one, cannot but feel some disquietude at the bigness of the task, and is impelled to raise the question whether one student can cover such a far-spread field critically. The internal evidence indicates a negative reply. For example the chapter on the tannins may be cited. The brief treatment assumes the efficacy of present methods of tannin-extraction, and takes no account of their total inadequacy for any physiological studies. Nor is any reference made to the useful and exhaustive bibliographic studies of Dekker, which would put the student in touch with that source of information too little known to physiologists. The same criticism may be made concerning the treatment of india-rubber, namely, that they are merely ordinary chemical analytical methods, no mention being made even of Whittelsey's important contribution to this aspect of the work, nor to those of Spence and of the reviewer on the behavior of rubber in the living plant. The physiologist will find in these chapters little to guide him even to work already done from his point of view. But it would be unjust to judge the whole book from the treatment of these more obscure subjects, since the meagreness of matter concerning them rests in part at least on our lack of knowledge.

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[1] Grafe, Victor, Ernährungsphysiologisches Praktikum der Höheren Pflanzen. Pp. 494, figs. 186. Berlin, Paul Parey, 1914. Mk. 17.00.

One finds, on the other hand, that the portion of the text devoted to methods for the study of the nutrition and growth of the seedling is quite full and extremely useful, and the same may be said of many other subjects, such as respiration, photosynthesis, and nitrogen assimilation, while the gas-analysis methods that play so important a part in the study of these matters, are described in detail. Of especial value are the chapters on sterilization of higher plants, methods of studying the surface tension of protoplasm (including Czapek's important contribution), the enzymes (Bunzel's highly refined methods here being presented), respiration and photosynthesis, in all of which many procedures not before collated in a single book, are brought together. A considerable space is devoted also to forcing, measurement of growth, of transpiration (including stomatal movements), bleeding pressure, and osmotic pressures.

There are throughout the book a number of striking omissions, an excuse for which is not at hand. No mention is made of the water culture methods of Livingston, and of Schreiner and Skinner, the latter especially important. Although Francis Darwin's porometer method is described, Ball's very ingenious "stomatograph" has escaped attention. Nothing is said of methods for studying evaporation, and their importance as a standard, as developed by Livingston and embodied in his conception of relative transpiration, although analogous methods, such as Wiesner's for measuring light intensities, do appear. Nearly all the devices for the study of transpiration are given excepting one form of potometer perhaps the most generally useful of the simple types, although the paper describing its earliest use is cited. Dixon's important thermoelectric method of determining the concentration of saps, is given.

One misses, however, indications of appreciation of the work of

Gager on the effects of radium, of Crocker and others on germination, and of Richards, MacDougal, Osterhout, Newcombe, and Green. One readily sees that other studies, which should rightly have found a place in such a book, are missing, though inasmuch as it is intended to comprehend methods rather than results, many of the most important works in the field of nutrition naturally would not be mentioned, since these frequently do not present new methods. We find however that this expectation is wrong, and that, on the contrary, much space is devoted to the presentation of results, many of which have been largely superseded by studies more recent than those actually cited. It is therefore not captious perhaps to say that a wiser selection of published results would have made the book more valuable. There are, moreover, indubitable indications that the author has taken only minor note of American work.

It would, however, be unjust to convey the impression that the book is of secondary importance. It is distinctly valuable, for whatever the omissions may be, it contains a plentitude of material, and it has the mission, conceived by the author, to bring the chemist and the plant physiologist onto common ground. An additional value of the book is found in a considerable number of useful tables in which are brought together in condensed form a good many data, though, as already indicated, some of these are superseded. Included among them is, *e.g.*, an extensive table of color indicators, derived from Friedenthal, especially important for the more accurate study of sap acidities. These valuable determinations, though well known to the physical chemists, are not sufficiently appreciated by the botanists, and it is in bringing many matters of similar value to theirattention, as well as in making an adequate summary for the biochemist of the chemistry of nutrition from the physiologist's point of view that Grafe's book will be especially appreciated.

In conclusion it may be fairly stated that his work, which has called for a very considerable and sustained effort on his part, contains a large body of information of undoubted value. The chief criticism is to be found in the very limited appreciation of the work of American botanists, who, it is rightly believed, have made worthy achievements in the field of plant nutrition. One gets the impression in running through the book page by page in order to estimate the author's acquaintance with the literature, that the citations of American studies are more a matter of chance than systematic research. And there is internal evidence that monographs which are known to have been available to the author (since they are distributed gratuitously to all the great libraries throughout the world) have not been made use of. The limited circulation of American botanical periodicals in Europe appears to indicate also that authors in that part of the world depend too largely on the assiduity displayed by Americans in the distribution of reprints.—FRANCIS E. LLOYD, MCGILL UNIVERSITY.

FLORA OF CALIFORNIA.—The fifth part of this important work,[1] issued early in February, comprises 62 pages, completing Portulaceaceae from *Calandrinia*, containing Caryophyllaceae, Ceratophyllaceae and Nymphaceae complete, and carrying Ranunculaceae through *Anemone*. It is illustrated with 13 text figures, those delineating the flowers of 11 species of *Silene* being particularly helpful. A new genus, *Eremolithia*, is proposed, based on a remarkable plant found in Owens Valley; *Achyronychia rixfordii* Brandegee, is the only new species. The steady progress of this great Flora is most gratifying, especially to western botanists.—S. B. PARISH.

[1] Jepson, W. L., A Flora of California. Part 5. Pp. 62, San Francisco, Cunningham, Curtis and Welch, 1915.

# NOTES AND COMMENT

The Plant World announces two prizes which are to be awarded for the best papers embodying original work in any phase of the water relations of plants. The amount of the first prize is $50, and of the second prize $15. The offering of these purses is made possible by the generosity of Prof. B. E. Livingston and by contributions from Dr. D. T. MacDougal, Prof. J. J. Thornber, Dr. J. B. Overton, Dr. H. C. Cowles, Dr. W. A. Cannon, and Mrs. Edith B. Shreve. Competing papers should be written so as to give no internal evidence of authorship, and should be sent to the Editor of The Plant World by December 1st, 1915. The manuscripts will be submitted to a committee of seven judges, whose names will be announced later, and the award will be made public on March 1st, 1916. The prizes will be withheld if it is the opinion of the judges that no paper has been submitted which is worthy of them. The second prize will be awarded at the discretion of the judges and may be added to the first prize if there is a wide hiatus between the merits of the two best papers. The Plant World reserves the right to publish any papers submitted in the contest, and in the case of such publication the author will be given an opportunity for the revision of his paper but not for any considerable extension of it.

The New York State College of Forestry is endeavoring to interest the high schools of that state in an enlargement of the function of arbor day, so that the planting of one or two shade trees will be replaced by the planting of one or two thousands of trees on some available piece of land suited only for forest growth. The boys and girls who have helped to plant a forest will undoubtedly take a deep interest in the protection and conservation of all forests.

The Biological Society of the Pacific met in San Francisco on February 27th to partake of a dinner, and to discuss plans for scientific meetings and field trips in connection with the session of the American Association in San Francisco in August.

# NOTES ON THE RELATIONS BETWEEN THE FLORAS OF SUBANTARCTIC AMERICA AND NEW ZEALAND

CARL SKOTTSBERG

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Ever since the father of antarctic botany, Sir Joseph Hooker, published his admirable Introductory Essay to his Flora Novae Zelandiae, the question of the relations between the various floras around the south polar regions has been the incentive to numerous investigations and speculations. Engler, in 1882,[1] summarized our knowledge of these things in a most instructive and lucid manner, and after him nearly every author who has written on the floras or faunas of the lands or islands concerned has fully understood the importance of dwelling upon the geographical distribution of each species, and the old theories of land connections or transmarine migrations have repeatedly been discussed. However, these authors seem to have used about the same lists of species, without keeping up with the taxonomic work always going on, and the last thirty years make numerous changes and additions necessary. A number of monographs of various genera and orders have appeared, several important discoveries have been made, and many old mistakes have been corrected. Among other publications used for this paper I might especially mention the numerous monographs in Engler's *Jahrbücher*, the *Pflanzenreich*, also edited by Engler, Domin's monograph on *Koeleria*, Bitter's monograph on *Acaena* (both in *Bibliotheca Botanica*), the scientific results of the recent antarctic expeditions, the new works on the flora of New Zealand, the Subantarctic Islands, etc.

Two circumstances have led me to take up again the problem of plant distribution in austral lands; first, the fact that I came to be fairly well acquainted with subantarctic and antarctic floras during my travels in those regions (Swedish South Polar Expedition, 1901 1903; Swedish Magellanic Expedition, 1907 1909), and secondly, that during the first of these expeditions members of our party discovered fossil faunas and floras in the now ice-covered Graham Land. Not that this was anything like unexpected, but the fact that we now were able to get a glimpse of the rich organic world that once inhabited lands now so barren and desolate, and to discuss its affinities in the surrounding or more remote countries, gave us, among other results, a sounder basis for our speculations on the origin of subantarctic and antarctic floras. Thus, I have tried to compile a new list of bicentric types on the basis of existing ones. However, I have found it better to confine myself to a comparison between Subantarctic America and New Zealand (with the Auckland, Campbell, and other islands), my knowledge of the Australian and Tasmanian flora, the known part of which is increasing rapidly, being much too limited. Only such types are treated as occur in the Dominion of New Zealand and in Subantarctic America (the Magellanic territories and Western Patagonia for reasons easy to understand here comprising the whole of the forest region of southern Chile and also the Falkland Islands and South Georgia). Cosmopolitan species or species of a wide range are excluded, also types which quite as well may have reached New Zealand and South America from the north. I have, however, quoted a few striking examples of bicentric occurrence in Australia or Tasmania and South America, even if the type in question does not belong to the New Zealand flora.

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[1] Engler, A., Versuch einer Entwickelungsgeschichte der Pflanzenwelt, ii, 1882.

Only the flowering plants are included. It is well known that cryptogams, by means of their minute spores, are likely to become very widely distributed, and that cosmopolitan forms are common in the different groups. At the same time they might very well be treated from the same point of view as the phaenogams. Such works as Christ's Geographie der Farne (1912) or Cardot's La Flore bryologique des terres magellaniques[2] clearly show that the problem remains the same, and Cardot seems to have treated his subject in a very able manner.

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[2] Cardot, J. in Wiss. Ergebn. d. Schwed. Südpolarexped., iv, 2, 1908.

The botanical museums in Sweden possess large collections from nearly all subantarctic lands as well as from New Zealand and the antarctic regions. Thus, in many cases it has been possible to make the necessary comparisons between specimens from different places. Through the kindness of one of the foremost botanists in New Zealand, Dr. L. Cockayne, I received a number of plants from that region representing species reported to be identical with South American ones. I take advantage of this occasion to thank him most heartily for his assistance.

In the following paragraphs the figures given in parentheses after the generic names indicate the number of species actually known. I have done my best to get these as exact as possible, but this is not easy. The orders follow according to Engler's Syllabus.

Taxaceae. *Dacrydium* Sol. (16): 7 belong to New Zealand, 1 to Tasmania, 4 to New Caledonia, 3 to south-eastern Australia, and 1, *D. Fonckii* (Phil.) Benth., to south Chile (extending to 52° 30′), apparently related to *D. laxifolium* Hook. f. in New Zealand.

Pinaceae. *Araucaria* L. (12; Australia, New Caledonia, Norfolk Id., New Guinea, 3 in South America) of the section Colymbea: 1 in Australia, 1 in Brazil, 1 in Chile (also 1 extinct, from southern Patagonia).

Cupressaceae. *Libocedrus* Endl. (8; 2 in New Zealand, 1 in New Caledonia, 1 in New Guinea, 1 in eastern Asia, 2 in Chile, 1 in California) *L. chilensis* Endl and *L. tetragona* (Lam.) Endl. in Chile, the latter extending to Fuegia, correspond to *L. Doniana* Endl. and *L. Bidwillii* Hook. f. in New Zealand. One species, probably *L. chilensis*, is fossil in Falkland Ids. *Fitzroya* Hook. f. 2, 1 in Chile between 39° and 43° S., the other (formerly regarded as the type of a separate genus, *Diselma*) in Tasmania.

Gramineae. *Agrostis magellanica* Lam. is found in southern Chile, Fuegia, Falkland Ids., Kerguelen, Marion. Id., Heard Id., New Zealand, and the Subantarctic Ids. *Poa foliosa* Hook. f. (Subantarctic Ids. of New Zealand) corresponds to *P. flabellata* Hook. f. (Fuegia, Falkland Ids., South Georgia). *Koeleria*, Sect. Dorsoaristatae (13) has 3 in New Zealand, 2 in eastern Australia and Tasmania, 2 in Asia, and 6 in Argentine and Patagonia (1 extending to Falkland Ids.). Domin thinks that the section is of South American origin, having wandered to New Zealand; however, when indicating the route used he puts it westward from Patagonia, the direction opposite to that generally accepted on account of the Antarctic Drift. *Hierochloa redolens* R. Br. (Victoria, Tasmania, New Zealand, Subantarctic Ids.) is very nearly related to *H. magellanica* Hook. f. (Fuegia, Falkland Ids.). Others think these identical, but Hackel and Pilger keep them distinct.

CYPERACEAE. *Oreobolus* R. Br. includes 4 species, 1 in New Zealand, 1 in New Zealand, Tasmania and Victoria, 1 in Sandwich Ids., 1 in southern Chile, Fuegia and Falkland. The New Zealand species, *O. pumilio* R. Br. and *O. strictus* Berggr. stand near the South American *O. obtusangulus* Gaud. *Carpha* R. Br. (2), *C. alpina* R. Br. in Auckland Id., New Zealand, Tasmania, Victoria, and New Guinea, and *C. schoenoides* Banks et Sol. in Fuegia. Clarke considered these to be identical. *Schoenus* L. (± 60, many in Australia and New Zealand). *S. pauciflorus* Hook. f. (New Zealand) hardly differs from *S. antarcticus* Hook. f. (Fuegia). *Carex Darwinii* Boott var. *urolepis* (Franch.) Kük. is found in Fuegia and in Chatham Id. *C. pumila* Thunb. extends from New Zealand over Tasmania and Australia to eastern Asia, and also occurs in Chile. *C. trifida* Cav. is found in Fuegia, Falkland Ids., New Zealand, Auckland Id., and Campbell Id. Of the section Bracteosae (6) 1 occurs in Mexico, 4 in South America (1 to southern Chile) and 1 in New Zealand. The section Echinochlaenae (20) has 16 species in New Zealand, 1 in Tasmania, 1 in Australia, 1 in Juan Fernandez, and 1 in southern Chile. Of the section Unciniaeformes subsection Aciculares (4) 3 are Andine (= 2 extend to the Falkland Ids.) and 1 is found in New Zealand, Tasmania, and Victoria. The genus *Uncinia* Pers. (24) is confined to America (Mexico and West Indies to Fuegia), Tristan d'Acunha, New Zealand, and Australia. One species reaches New Guinea, and 1 Kerguelen and North Amsterdam Id., both belonging to the section Stenandrae, including 17 species. Of these 13 occur in New Zealand (7 being endemic), 4 in temperate and subantarctic America, 1, *U. macrolepis* Dcne. is found in Chile and in New Zealand.

RESTIONACEAE. *Leptocarpus* R. Br. (21) : 1 in New Zealand, 11 in Australia, 1 in eastern Asia, 7 in South Africa, and 1 in Chile.

CENTROLEPIDACEAE. *Gaimardia* Gaud. (3), *G. australis* Gaud. (Fuegia, Falkland Ids.) corresponds to *G. setacea* Hook. f. in New Zealand. The third species in Tasmania.

JUNCACEAE. *Marsippospermum* Desv. (3), *M. gracile* (Hook. f.) Buch. in New Zealand, Auckland and Campbell Ids. is nearly related to *M. Reichei* Buch. (Patagonian and Fuegian Andes). The third species, *M. grandiflorum* L. f. occurs in Patagonia, Fuegia and the Falkland Ids. *Rostkovia* Desv. (monotypic), *R. magellanica* (Lam.) Hook. f. in Magellan, Falkland, South Georgia, and Campbell Id. *Juncus* L. *J. planifolius* R. Br. in Auckland Id., Chatham Id., New Zealand, Tasmania, Australia and south Chile. In the Pflanzenreich Buchenau's 29th Section of this genus comprises 7 species, all nearly related; of these 2 belong to the New Zealand district and 5 to the southern Andes, some reaching Fuegia, Falkland Ids., and South Georgia. One of the American species, *J. scheuchzerioides* Gaud., is reported from New Zealand, and the Auckland, Campbell and Antipodes Ids., but there is reason to doubt the identity of the plants from these localities. *Luzula racemosa* Desv. *typica* occurs from Mexico to Fuegia; the varieties *Traversii* Buch. and *ulophylla* Buch. represent the species in New Zealand.

LILIACEAE. *Astelia* Banks et Sol. (12) has its headquarters in New Zealand, with 6 species; the others being in Australia, Fiji, and the Sandwich Ids., with 1, *A. pumila* R. Br. in Fuegia and the Falklands Ids. The last-named species has been considered as corresponding to *A. linearis* Hook. f. (New Zealand, Auckland Id., Campbell Id.), but the two do not seem to be very near each other.

*Enargea* Banks et Sol. (3); *E. polyphylla* (Hook.) F. v. M. in south Chile and western Patagonia, *E. marginata* (Gaertn.) B. & H. in Magellan and Falkland Ids., and *E. parviflora* (Hook. f.) Skottsb. in New Zealand, generally considered to be identical with *E. marginata.* I have found it necessary to reëstablish Hooker's *Callixene parviflora:* leaves with veins distinctly prominent on lower surface, even the transverse ones, margins of leaves perfectly smooth, flowers 1–2 cm. across, with all parts smaller, berry whitish, whereas *E. marginata* proper has obsolete veins, the transverse ones never being visible, the leaves have scabrous margins, the flowers are 2–3 cm. across, with larger stamens and style, and the berry dark purple.

IRIDACEAE. *Libertia* Spreng. (9): 5 in Chile (1 extending to the Patagonian channels at least), 3 in New Zealand (1 also in Tasmania and Australia), 1 in Australia. *L. elegans* Poepp. (Chile) stands near *L. ixioides* Spreng. (New Zealand). The latter is incorrectly credited to Chile.

FAGACEAE. *Nothofagus* Blume (17) is a striking example of bicentric distribution. There are 6 species in New Zealand, 1 in Tasmania, 1 in Tasmania and Victoria, 1 in New South Wales, 8 in Chile (some extending to the Argentine slopes of the Andes, 3 extending to Fuegia). The evergreen section is represented by 6 species in New Zealand (the whole number found there), by 1 in Tasmania and Victoria, 1 in New South Wales, and 3 in Chile; the deciduous-leaved by 1 in Tasmania and 5 in Chile.

PROTEACEAE. *Lomatia* R. Br. (9): 2 in Tasmania, 4 in eastern Australia, 3 in Chile (1 extending to the Patagonian channels). *Embothrium* Forst. (5): 4 in South America (1 extending south to Fuegia), 1 in eastern Australia. *Orites* R. Br. (8): 4 in Tasmania, 1 in Victoria, 1 in New South Wales, 1 in Queensland, and 1 in the Chilean Andes.

LORANTHACEAE. *Phrygilanthus* Eichl. (25–30): two-thirds of the species in South America from Mexico to southern Chile, 4 in Australia, 2 in New Zealand.

POLYGONACEAE. *Muhlenbeckia* Meissn. (21): 3 in New Zealand, 1 in New Zealand, Tasmania and Australia, 6 in Australia, 1 in the Solomon Ids., 10 in South America (Mexico to Chile).

CARYOPHYLLACEAE. *Colobanthus* Bartl. (19–20), a difficult genus, where a revision seems necessary. There are 9 species in New Zealand and the Subantarctic Ids. (1 of these also found in Victoria, 2 also in South America), 8 additional species occur in the Andes from Ecuador to Fuegia, Falkland Ids., and South Georgia, 1 in Kerguelen Id., 1 in New Amsterdam Id., 1 in Tasmania and Victoria. The two species common to the New Zealand region and South America are *C. quitensis* Bartl. and *C. crassifolius* (D'Urv.) Hook. f. (= *C. Billardieri* Fenzl p. p.). *C. Billardieri* from Tasmania and Victoria (*Spergula apetala* Lab.) seems distinct, *C. apetalus* (Lab.). *C. subulatus* (D'Urv.) Hook. f. (= *C. Benthamianus* Fenzl) of New Zealand and Campbell Id., also reported from Victoria, differs from true *subulatus* (Fuegia, Falkland Ids., South Georgia) in being *pentamerous;* it is probably a different species.

RANUNCULACEAE. *Caltha* L. sect. Psychrophila includes 6 species: 2 in New Zealand, 1 in Tasmania and Australia, 3 in the Chilean Andes and Fuegia (2 in the Falkland Ids.). The species from New Zealand and Australia stand near the American *C. sagittata* Cav. *Myosurus aristatus* Benth. is reported from California, Chile, Patagonia, Fuegia and New Zealand. *Ranunculus acaulis* Banks et Sol. has been found in south Chile, Falkland Ids. (the author in 1907), New Zealand, Chatham Id., Auckland Id. *R. crassipes* Hook. f. (Kerguelen Id., Macquarie Id.) is so near *R. biternatus* Sm. (Fuegia, Falkland Ids., South Georgia, Marion and Crozet Ids., New Amsterdam Id.) that most authors consider them to be identical. However, I do not join in this judgment. The leaves are very different, the first mentioned generally has tetramerous flowers, the latter pentamerous. Unfortunately the material of *R. crassipes* at hand is too scanty for confirming my impression that there are other differences in the flower and fruit. Cheeseman kept them separate in his Flora (1906), but later (Subantarctic Ids. of New Zealand II, 1909) reduced them to 1 species, pointing out that Macquarie Id. specimens have their leaves almost as much divided as *R. biternatus* from Punta Arenas, figured by Wildeman in the Botany of the Belgica Expedition (plate xii). However, Wildeman's determination is incorrect, for the plate in question represents quite another species, *R. fuegianus* Speg.

MAGNOLIACEAE. *Drimys* Forst. (17): 3 in New Zealand, 4 in Australia, 1 in New Guinea, 4 in New Caledonia, 1 in Lord Howe Id., 1 in Borneo, 1 in Venezuela, 1 in Brazil, 1 in South America from Mexico to Fuegia. *D. winteri* Forst. somewhat corresponding to *D. axillaris* Forst. in New Zealand.

MONIMIACEAE. *Laurelia* Juss. (3): *L. Novae Zelandiae* A. Cunn. in New Zealand, *L. sempervirens* Tul. and *L. serrata* Phil. in south Chile. It is very near the Australian *Atherosperma*.

CRUCIFERAE. *Cardamine glacialis* (Forst.) DC. is found in Chile to Fuegia, and Falkland Ids., in New Zealand, Auckland and Campbell Ids.

DROSERACEAE. *Drosera* L. sect. Psychophila (3): 1 in New Zealand, 1 in New Zealand, Tasmania and Australia, and 1 in south Chile, Fuegia and Falkland Ids.

CRASSULACEAE. *Crassula moschata* Forst. (Chile to Fuegia, Falkland Ids., Kerguelen Id., Marion, Id., New Zealand and Subantarctic Ids.) is circumpolar.

ROSACEAE. *Geum parviflorium* Sm. and *G. magellanicum* Comm. in south Chile, Fuegia and New Zealand. Of the former I have compared specimens from both regions; the New Zealand ones are more villous, with very long hairs, the others have the leaves sparingly pubescent and a much shorter and denser pubescence on the upper part of the scapes. I have seen no materal of *G. magellanicum* from New Zealand. A third species, *G. albiflorum* (Hook. f.) Cheesem. (Auckland Id.) is very near *G. parviflorum*. *Acaena* L. sect. Acrobyssinoidae includes 6 species in Chile and Fuegia (1 also in South Georgia) and 1 in Tasmania. *Acaena* sect. Ancistrum, subsect. Euancistrum has two groups (17) ranging from temperate South America to Falkland Ids., 1 (2) in New Zealand, 1 (3) with 1 in New Zealand, Tasmania and Australia, 1 in New Amsterdam Id., and 1 in Tristan d'Acunha. The group Laevigatae includes 1 in south Chile, Fuegia and Falkland Ids., and 1 in New Zealand. Whether *A. adscendens* Vahl (Magellan, Falkland Ids., South Georgia, Prince Edward and Crozet Ids., Kerguelen Id.) really occurs in Macquarie Id. is an open question.

LEGUMINOSAE. *Sophora tetraptera* Ait. coll. with varieties or subspecies in New Zealand, Lord Howe Id., Easter Id., Juan Fernandez and south Chile.

GERANIACEAE. *Geranium* L. sect. Chilensia (23): 22 are found in South America (most of them are Chilean) and 1 in Australia, Tasmania and New Zealand. Near this section stands sect. Australiensia with 1 in Java, 1 in Australia, Tasmania and New Zealand, and 1 in Chatham Id. Sect. Andina (17) is Andine, but one species, *G. sessiliflorum* Cav. (South America to Fuegia) also occurs in New Zealand and Tasmania.

OXALIDACEAE. *Oxalis magellanica* Forst. from Fuegia is generally considered to be identical with *O. lactea* Hook. (= *O. catarractae* A. Cunn., *O. Novae Felandiae* Gdgr.) in New Zealand, Tasmania and Victoria. I am not so sure of this, for while my Fuegian specimens quite agree with the original description of Forster the others (I saw material from New Zealand only) differ —and this is evident also from the description of Bentham in Flora Australiensis—in having distinctly obcordate leaflets with narrow base, and in the pedicel attaining a length of 1–4 cm., whereas I never saw it exceed 1 cm. in the true *O. magellanica.* The flowers of *O. lactea* measure 1 cm. across; which is twice as much as in the other.

CORIARIACEAE. *Coriaria* L. (8, Mediterranean region, Asia, New Zealand, South America). *C. ruscifolia* L. in south Chile, New Zealand, Kermadec Id. and Chatham Id. *C. thymifolia* H. B. K. Mexico to Peru, New Zealand.

RHAMNACEAE. *Discaria* Hook. (16–18): all in extratropical and andine South America (1 extending to Fuegia), except 1 in New Zealand, and 1 in Australia.

ELAEOCARPACEAE. *Aristotelia* L'Her. (9–11): 3–4 in New Zealand, 1 in Tasmania, 2 in Australia, 1 in New Guinea, 1 in New Hebrides, 1–2 in Chile. *A. racemosa* Hook. f. (New Zealand) stands near the Chilean *A. maqui* L'Her.

EUCRYPHIACEAE. Monotypic order. *Eucryphia* Cav. (4–5): 2 in Chile (*E. patagonica* Speg. possibly a third), 1 in Tasmania, 1 in New South Wales.

THYMELAEACEAE. *Drapetes* Banks (6), forming a separate suborder, has 3 in New Zealand, 1 in Australia and Tasmania, 1 in Borneo and 1 in Fuegia and Falkland.

MYRTACEAE. The Metrosiderinae group: several genera in New Zealand, Australia, Polynesia, Malayan region, and 1 *Metrosideros* in Cape Colony; one representative in South America, the monotypic genus *Tepualia* Gris. (south Chile to Magellan). The main stock of the closely allied genus *Metrosideros* Banks is in New Zealand (11).

OENOTHERACEAE. *Epilobium* L. sect. Sparsiflorae includes 4–5 species in New Zealand, 1 in Tasmania, and *E. conjungens* Skottsb.—at least nearer to this section than to any other—in Fuegia (see Skottsberg in Wiss. Ergebn. der Schwed. Südpolarexped. IV: 4, 1906). *Fuchsia* L. (60): 3 confined to New Zealand, all the rest are American (Mexico to Fuegia).

HALORRHAGIDACEAE. *Myriophyllum elatinoides* Gaud. in extratropical South America to Fuegia and Falkland Ids., and in New Zealand. *Gunnera* L.: of the two closely related subgenera of small herbs *Milligania* is confined to New Zealand and Tasmania, *Misandra* to south Chile, Fuegia and Falkland Ids.

ARALIACEAE. *Pseudopanax* Koch as limited by Harms and Seemen comprises 7 species, 5 belonging to New Zealand and 2 to south Chile (1 extending to Magellan).

UMBELLIFERAE. *Hydrocotyle americana* L. has been found in North and South America and in New Zealand. *H. hirta* R. Br. has been reported from Chile, Patagonia, Falkland Ids. and Australia. *H. Novae Zelandiae* DC. and *H. microphylla* A. Cunn. seem to come near the Chilean *H. marchantioides* Clos. and *H. Bonplandii* Kth. *Azorella selago* Hook. f. is known from Fuegia, Falkland Ids., Marion and Crozet Ids., Kerguelen Id., Heard Id., and Macquarie Id., thus belonging to the circumpolar type. *Schizeilema* Domin. (12): 2 in South America (Patagonia, Fuegia, Falkland Ids.), 9 in New Zealand and the Subantarctic Ids., and 1 in Australia. *Crantzia lineata* Nutt. in the United States, Mexico, South America, to Fuegia and the Falkland Ids., New Zealand, Australia, and Tasmania. The form in Pacific North America is now held to be a separate species, *C. occidentalis* (Coulter and Rose as *Lilaeopsis*). *Oreomyrrhis* Endl. (5–6): all American (Mexico, Fuegia, Falkland Ids.), one of them, *O. andicola* (Lag.) Endl. in different varieties also in New Zealand, Chatham Id., Tasmania, and Australia. *Apium australe* Thouars (south Chile, Patagonia, Fuegia, Falkland Ids., and Tristan d'Acunha) is so near *A. prostratum* Labill. (New Zealand, Kermadec Id., Tasmania, and Australia) that they are united by many authors. Some argue that both are only forms of *A. graveolens* L.

CORNACEAE. *Griselinia* Forst. (6): 4 in central and south Chile (1 with a variety in Brazil) and 2 in New Zealand.

ERICACEAE. It seems that the group Prionoteae of the Epacridaceae, often dwelt upon as being the sole members of that order in America, should find a more suitable place among the Ericaceae, on account of the non-existence of essential epacridaceous characters, especially in the dehiscence of the anthers. According to most authors the group includes two genera, *Prionotes* R. Br. and *Lebetanthus* Endl., both monotypic, the latter formerly known as *Prionotes* also. I can not find any valid, distinctive characters (the loculi of the capsule are many-seeded in both!), thus we have one genus, *Prionotes*, with *P. cerinthoides* Labill. in Tasmania, and *P. myrsinites* (Lam.) Skottsb. in Fuegia. The genus seems to form a link between the two orders spoken of. *Gaultheria serpyllifolia* (Lam.) Skottsb. (= *G. microphylla* Hook. f.) stands near *G. antipoda* Forst. in Tasmania and New Zealand. *Pernettya* Gaud. (20 ±) all American (Central America to Fuegia and Falkland Ids.) except *P. tasmanica* Hook. f. (Tasmania; forming the monotypic section *Perandra*) and *P. nana* Col. (New Zealand; an Eupernettya, as are all the rest of the genus).

PRIMULACEAE. *Samolus repens* Pers. in South America, and in New Zealand and surrounding islands, Tasmania, Australia and New Caledonia.

GENTIANACEAE. According to Grisebach *Gentiana* sect. Andicola comprises about 50 species, all Andine except 2, 1 in New Zealand, the other in Tasmania; Sect. Antarctophila includes only a few species: 1 in Tasmania, 1 in Australia and New Zealand, and 1 in south Chile, Fuegia and Falkland Ids.

BORAGINACEAE. *Myosotis* L. (50 ±): 24 in New Zealand (1 also in Australia) and surrounding islands. In America only 2 species, 1, *M. antarctica* Hook. f. hitherto known from New Zealand, but found by the author in south Patagonia; the second, *M. albiflora* Banks et Sol. endemic in Magellan, but related to the New Zealand species.

TETRACHONDRACEAE (See the author's paper in Engler's Jahrb., 1912). A monotypic order: *Tetrachondra* Petrie (2): *T. Hamiltonii* (Kirk) Petrie in New Zealand, *T. patagonica* Skottsb. in Patagonia, nearly related to each other.

SCROPHULARIACEAE. *Jovellana* R. & P. (4–6): 2 in Peru and Chile, 2(–4) in New Zealand. *Ourisia* Comm. (28): 7 in the subtropical Andes, 12 in Chile, 8 in New Zealand, and 1 in Tasmania. *Gratiola peruviana* L. in South America, New Zealand, Tasmania, and Australia. *Veronica* L. sect. Hebe includes 75–80 species, of them 67 are endemic in New Zealand, 1 in New Zealand and eastern Australia, and *V. elliptica* Forst. in New Zealand and the Subantarctic Ids., Fuegia and Falkland Ids. I have compared a set of specimens in flower and fruit from New Zealand, Fuegia and Falkland Ids. The Falkland plants differed in having slightly shorter, broader and much more obtuse calyx and corolla lobes and a shorter style, but the Fuegian specimens agreed very well with those from New Zealand. The rather variable *Veronica salicifolia* Forst. from New Zealand also includes *V. Fonckii* Phil. found in south Chile between 44° and 45° S. (*Euphrasia antarctica* Benth. has been reported from South America and New Zealand, but Wettstein showed that the latter plant is a very distinct species, *E. zealandica* Wettst. All the species in New Zealand and Australia belong to Sect. I, Eueuphrasia, while the Chilean and other plants form Sect. II, Trifidae).

PLANTAGINACEAE. *Plantago* L. sect. Plantaginella (13): 9 Andine (Mexico, to Fuegia and Falkland Ids.), 1 in New Zealand, 1 in New Zealand, Auckland Id., and Tasmania, 1 in Tasmania, and 1 in Australia.

RUBIACEAE. *Nertera* Banks et Sol. (8–9). 2 in eastern Asia, 1 or 2 in the Philippine Ids., 1 in Australia and 4 in New Zealand, among the latter *N. depressa* Banks having a very wide distribution (New Zealand, Auckland and Campbell Ids., Tasmania, Australia, Tristan d'Acunha, Mexico to Fuegia, Falkland Ids., Juan Fernandez, and the Sandwich Ids.).

CAMPANULACEAE. *Pratia* Gaud. (20 ±): 3 in New Zealand, 4 in Australia, 1 in New Guinea, 3 in Asia, 1 in the Philippine Ids., about 8 from Andine South America to Fuegia and Falkland Ids.

GOODENIACEAE. *Selliera* Cav. (2): 1 in West Australia, the other, *S. radicans* Cav. in New Zealand, Tasmania, Australia, and Chile.

STYLIDIACEAE. An order nearly confined to the Australian region, especially richly developed in West Australia; 3 species of *Stylidium* (103) in the monsoon region. *Phyllacne* Forst. (4): 3 in New Zealand (1 also in Auckland Id. and Campbell Id.), 1 in Fuegia.

DONATIACEAE. A monotypic order. *Donatia* Forst. (2): *D. fasciculata* Forst. in south Chile and Fuegia, *D. Novae Zelandiae* Hook. f. in New Zealand (and Tasmania?).

COMPOSITAE. *Lagenophora* Cass. (16): 6 in New Zealand, 4 in Australia, 1 in Fiji, 1 in Sandwich Ids., 4 in Andine South America (1 extending to Fuegia and Falkland Ids.). *L. Forsteri* DC. (New Zealand) stands rather near the Chilean species. *Cotula* L. (50–60) sect. Leptinella: well developed in New Zealand (17), some of the species, especially *C. plumosa* Hook. f. (New Zealand, Subantarctic Ids., Crozet Id., Kerguelen Id.) is near *C. scariosa* (Cass.) Franch. (south Chile to Fuegia and Falkland Ids.). *Abrotanella* Cass. (14): 7 in New Zealand, 2 in Tasmania, 1 in Victoria, 1 in Rodriguez Id., 3 in subantarctic America. *A. muscosa* Kirk (New Zealand) is closely allied to *A. emarginata* Cass. (Fuegia, Falkland Ids.), others, as *A. caespitosa* Petrie and *A. spathulata* Hook. f. (New Zealand), are related to the Fuegian *A. linearifolia* Gray and *A. submarginata* Gray.

There are 49 natural orders represented in the above list. Even if, as I hope, a number of new examples have been added, this does not of course influence the nature of the problem. We know, just as we did before, that, *judging from the actual distribution of plants*, there is an Australian and New Zealandic element in Andine and Subantarctic America, that there is an Andine element in New Zealand and Australia, and that there remain genera, or even orders, which are virtually bicentric and form what one might perhaps call the Old Antarctic element. Here are examples of the three groups: (1) *Dacrydium*, *Carices Echinochlaenae*, *Leptocarpus*, *Astelia*, *Lomatia*, *Embothrium*, *Orites*, *Drimys*, *Aristotelia*, *Drapetes*, *Tepualia*, *Epilobium conjungens*, *Pseudopanax*, *Myosotis*, *Veronica* sect. *Hebe*, *Phyllacne*, *Lagenophora*, *Cotula* sect. *Leptinella*; (2) *Carices bracteosae*, et *aciculares*, *Enargea*, *Phrygilanthus*. *Acaenae Acrobyssinoideae*, *Euancistrae* et *Laevigatae*, *Gerania chilensia*, *Discaria*, *Fuchsia*, *Azorella*, *Oreomyrrhis*, *Pernettya*, *Jovellana*, *Ourisia*, *Plantago*, sect. *Plantaginella*; (3) *Oreobolus*, *Carpha*, *Uncinia*, *Gaimardia*, *Marsippospermum*, *Rostkovia*, *Libertia*, *Nothofagus*, *Laurelia*, *Muhlenbeckia*, *Colobanthus*, *Caltha* sect. *Psychrophila*, *Drosera* sect. *Psychophila*, *Eucryphia*, *Gunnera*, *Prionotes*, *Tetrachondra*, *Pratia*, *Donatia*, *Abrotanella*.

We must certainly remember that the present distribution is often a poor indicator, that, for instance, a genus now well represented in New Zealand, with few species in South America, may have been much more plentiful in the latter country in bygone times, or that an Antarctic type may have developed many species in one place and few in the other.

I shall try to summarize the opinion of certain important authors on the problem of the bicentric subantarctic types. In the beginning of this paper I quoted Hooker's Flora Novae Zelandiae. If we can not at this date subscribe to everything that he wrote 60 years ago, we can on the other hand hardly deny that the reasons he advanced with such clearness and accuracy against explaining the puzzling distribution of many types simply by adopting a "double creation" or a migration of seeds right across the oceans, are still valid. It stands to reason that even with such plants as have suitable means of dispersal, a coincidence of chances is required for a successful migration, and for a great many it is most improbable that they ever covered such enormous distances under conditions similar to those of the present day. Even Wallace and Engler, who are thoroughly opposed to the bold theories of sunken continents, admit the Antarctic Continent may have been a source from which both South America and New Zealand have derived species, and that it once formed some sort of a passage between the two.

Diels (Engler's Jahrb. 22, 1897) has treated the question in an admirable way, showing how geographical, and thereby climatic changes affected the New Zealand flora, referring to the strong evidences of the existence of much more land on that side of the pole as late, perhaps, as in the Pliocene.

Schimper and Schenck (Wiss. Ergebn. d. Deutsch. Tiefsee-exped. Valdivia, II, 1905) think that the configuration of the land has been much the same as now, at least since the early Tertiary, and that there never was a connection between the Antarctic Continent and the lands surrounding it, the depth of the ocean being too great to permit any interpretations of this kind.

Werth (Deutsch. Südpolarexped. 8, 2) is opposed to such views finding that we must reckon with the Kerguelen flora as being largely of Preglacial age and as occupying more land at that time than at present, or we shall not come to an acceptable explanation of the present plant distribution. He admits that Postglacial migrations can have taken place, but denies that they would suffice to explain the actual floras.

Cheeseman, in his recent memoir (The Subantarctic Islands of New Zealand, vol. 2, 1909) adopts the view of Schimper, at least for the dispersal of circumpolar species which, if they could travel to Kerguelen from Fuegia might as easily continue their course from there and finally reach Macquarie Island or other places. However, he admits the possibility of a land connection between South America and the Antarctic, as well as a larger New Zealand, bringing it nearer to Victoria Land; a direct communication on that side he finds very improbable.

Chilton (Ibid., Summary of Results) is strongly impressed by the great number of facts derived from botany and zoology and unanimously pointing towards an old Antarctic fauna and flora that has spread in various directions, helped by land connections. He is especially struck with the discovery of fossil plants in Graham Land.

I shall now say a few words on the significance of this interesting event.[3] As is well known, fragments of fossil wood have been obtained also in Victoria Land. In Hope Bay, Louis Philippe Peninsula (Graham Land) a rich Jurassic flora of ferns and conifers, among them an *Araucarites*, was found by Prof. J. G. Andersson. There is also one Cretaceous plant reported from the same locality, probably a *Sequoia*. The fossil wood of Seymour and Snow Hill Islands, collected by the members of the same expedition, especially by Andersson and O. Nordenskjold, includes *Podocarpoxylon*, *Laurinoxylon* and *Nothofagoxylon*, belonging to the Upper Cretaceous or more probably to the Tertiary, and one *Phyllocladoxylon* and one *Dadoxylon* (*Araucaria*) which are known to be Tertiary. Dusén judges the stratum containing the fossil leaves to be of Oligocene age. The reader gets the impression that the determination of several species is very doubtful, and I shall only mention those in which there can not be much question about the identification: *Miconiiphyllum australe* Dus. (at least a Melastomacea!), *Laurelia insularis* Dus., *Drimys antarctica* Dus., *Lomatia angustiloba* Dus., *L. brevipinna* Dus., *L. serrulata* Dus., *L. seymourensis* Dus., *Knightia Andreae* Dus., *Fagus Dicksonii* Dus., *F. obscura* Dus. (if really *Fagus* and not *Nothofagus*), *Nothofagus magellanica* Engelh., *N. pulchra* Dus., *Araucaria imponens* Dus., and some ferns. With the single exception of *Miconiiphyllum* all are of profound interest for the question dealt with in this paper. Dusén denies that the Seymour flora shows any relation to New Zealand, and points out that *Knightia Andreae*, which he compares with *Knightia excelsa* R. Br., is the only hint at an affinity with Australia, although this plant is not a member of the Australian flora but endemic in New Zealand. *Phyllocladoxylon*

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[3] Dusén, P., Über die tertiäre Flora der Seymour-Insel. Wiss. Ergebn. d. Schwed. Sudpolarexped., iii, 3, 1908; Gothan, W., Die Fossilen Holzer der Seymour und Snow Hill Inseln. Ibid., iii, 8, 1908; Halle, J. G., The Mesozoic Flora of Graham Land. Ibid., iii, 14, 1913.

*antarcticum* Gothan is another example of the New Zealand element in the Seymour flora, not found in South America.

With these facts at hand it becomes evident that there existed an Antarctic Tertiary flora bearing resemblances to the present floras of Subantarctic America, New Zealand and Australia, and that the Antarctic Continent may have been a centre of evolution from which animals and plants wandered north. It is possible that the endemic element in other austral insular floras had the same origin, as for instance a type like *Pringlea*, now limited to the Kerguelen group. There probably also took place an interchange of species across the South Polar lands. I have already mentioned that a great many biologists, as well as geologists, believe in a formerly much larger Great New Zealand. And for Subantarctic America it seems probable that the Falkland Island were connected with the mainland at some time during the Tertiary. Both geological and bathymetrical conditions speak in favor of the well-known hypothesis boldly continuing the Andes over South Georgia, the South Sandwich and South Orkney Islands to Graham Land. That the sea between some of the links in this broken chain can not be styled as shallow, I do not regard as an insurmountable obstacle, for we know that the upheaval of the Andes was connected with the submersion of land, so that enormous depths of recent origin resulted right along the present coast line of Chile. The Antarctic Continent may have been more extensive in Preglacial time. The upheaval of the once ice-covered parts of Europe and North America after the recession of the inland ice has been interpreted as due to a tendency in the earth's crust to regain isostatic conditions, the weight of the ice having caused a considerable depression. Such a theory may as well be applied to the Antarctic Continent, submerged under the tremendous pressure of the most extensive inland ice that ever existed (save for the time when the same ice sheet was larger still than it is now).

Even if we admit Tertiary land communications, or at least much greater facilities for the migrations of plants and animals than now, everything in the present distribution can not be explained in this way. South Georgia offers a good example of this.

While there are numerous peculiar cryptogams, not one of the higher plants is endemic except the subspecies *Austro-Georgiae* Bitter of *Acaena adscendens* Vahl. It seems hardly possible that the higher flora survived the Glacial Epoch; it must have reached this isolated island in Postglacial time, originating from the Magellan Lands, where all the species in question are at home. Other islands may, of course, have received part of their flora in the same manner. Naturally, it lies at hand to interpret in this way the distribution of such species as range over the whole Subantarctic America, having additional stations in the New Zealand region—or the reverse and such as belong to the truly circumpolar group. I can come to no other conclusion than that the present distribution of the organic world in the austral region is due to a combination of old wanderings, the extinction of certain species during the Ice Age, the survival of others, and finally transoceanic migrations, which, if they ever took place, are still going on.

# ATMOMETRY AND THE POROUS CUP ATMOMETER

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## IV

### THE RADIO-ATMOMETER

*The Instrument and its Use.* The porous cup atmometer, as has been seen, exposes an imbibed porous evaporating surface in much the same way as the evaporating surfaces of organisms are exposed. Our discussion of the instrument has thus far dealt with it as a means for studying the evaporating power of the air as this influences water loss from plants and animals. The term evaporating power of the air implies the power of the air to remove water from some arbitrarily adopted standard surface and it is calculated to include the effects of air temperature, air humidity and air movement. As has been mentioned, however, the temperature of the surface plays an important role in determining the rate of water loss, and this surface temperature may not always depend merely upon air temperature; may be strongly influenced by conditions effective within the instrument, as by the temperature of the contained water mass. It is very difficult to distinguish between the influences exerted by these two sources of heat in evaporation phenomena and no serious attempt has yet been made in this direction.

There is, however, another important influence frequently exerted upon the evaporation rate from any surface, which may or may not be related to the surface temperature but which is distinctly *not* related to air temperature; nor is it directly related to any other atmospheric condition. This is the intensity of *radiant heat absorption* by the evaporating surface. This absorption is of course dependent upon the intensity of the impinging rays and upon the absorptive power for these rays, possessed by the surface in question. Practically the only radiant energy in nature, with which students of evaporation and plant transpiration are apt to be concerned, is that from the sun. Our discussion will have mainly to do with this.

To make the matter before us clear, let it be supposed that an ordinary standardized porous cup is operated in the open, in the vertical position. As the sun rises in the morning its rays strike one-half of the evaporating surface, their direction being approximately perpendicular to the long axis of the cup. Now, if any of the impinging radiant energy (heat, light) is absorbed by the cup, this should increase the rate of water loss on the sunny side. With a given intensity of impinging radiation the amount absorbed by the surface is determined by the absorbing power of the latter and by the angle at which the rays strike. In the case here supposed, the white porcelain cup possesses low absorbing power and a large proportion of the impinging energy is reflected. But the white cup does of course possess *some* absorbing power. Of the various parts of the illuminated surface, that portion receiving the rays most nearly perpendicularly must of course absorb the most energy. This portion is represented by a line on the cylindrical surface, marking the middle of the illuminated area. At the edges of this area the angle of incidence of the radiation vanishes, and between the middle line and the edge this angle ranges in magnitude from 0° to 90°. But, for a given kind, intensity and direction of radiation, the total absorption of energy should remain approximately the same for the whole illuminated area taken together, no matter what side of the cup is illuminated. If the average angular exposure of the cup to the impinging radiation might be kept the same throughout the day, and if all parts of the cup surface might have just the same absorbing power, then the effect of sunlight in accelerating evaporation should simply be added to the effects of the atmospheric evaporating power, from minute to minute or from hour to hour.

As the sun carries out its daily march, however, the angle or incidence of its rays upon a vertical cylindrical cup varies markedly. At noon the area of the cup receiving rays perpendicularly is usually (depending upon latitude and season) but a small portion of the hemispherical tip. At sunset again, this area is approximately represented by the middle line of the illuminated area, just as at sunrise, but on the opposite side of the cup. If it were not for the fact that the absorbing power for radiation, of the white porous porcelain, is very low, these conditions would vitiate the atmometric readings as indicating the evaporating power of the air. Actually, this atmospheric evaporating power can be measured only in the absence of appreciable radiation; practically, the absorbing power of the white porcelain is so low that the entire influence of sunshine may be neglected, for most purposes at least. The radiation is received but is almost entirely reflected and not absorbed.

The mean angular exposure of the cup to the sun's rays, may be held constant by placing the instrument obliquely instead of vertically, the tip pointing northward (in the northern hemisphere) and the whole cup so tilted that the sun's rays will continue all day to impinge perpendicularly to the long axis of the cup. Such a position is not the same throughout the year, however, and frequent adjustments are necessary; the cup should be the most nearly vertical at the winter solstice and most nearly horizontal at that of summer. Such changes in the position of the cup might result in differences in its effective exposure to air movement, and for most lines of study it is probably best—and it is certainly satisfactory—to give the cup the vertical position and to neglect the possible variation in exposure due to angular variations with reference to solar radiation. This refers to ordinary measurements of the evaporating power of the air, where the influence of sunshine is not particularly considered.

The possible influence of sunshine upon evaporation, having been once appreciated, it became desirable to devise some means by which this influence might be approximately measured. Especially is this needed for analytical studies of the conditional control of plant transpiration, where the absorption of radiant energy by foliar surfaces is frequently more important than the atmospheric evaporating power itself.

At first thought it seems feasible to expose two quite similar atmometer cups, one shaded from the sun's rays and one exposed to them, and to derive from the differences between their rates of evaporation a measure of the power of the sunshine to accelerate this process. But to do this it is requisite to give the two instruments the same exposure in all other respects, and the problem of establishing shade conditions without also modifying wind conditions, for example, is a very difficult one.

An alternative method was suggested. Let one cup remain white and let the other be blackened, so as to absorb as much radiation as possible, and let the two be exposed side by side without any shade. The difference between the readings of the two instruments should be a measure of the effectiveness of the sun's rays (during the particular time period in question) in promoting evaporation. To avoid the difficulty pointed out above, let both cups have an oblique position, such that the sun's rays will fall perpendicularly to the long axis throughout the day Such an arrangement was first tested at the Desert Laboratory, during the summer of 1907, with such promising results that considerable attention has since been given to its perfecting, as the *radio-atmometer*.[27]

Porous cups were finally obtained, of the usual form but dark brown in color and exhibiting a high power of light-heat absorption. Also white cups were blackened by the use of washed lampblack and also (a suggestion of Prof. F. E. Lloyd of McGill University) by the use of the so-called water-proof liquid drawing ink obtainable from dealers in artists' supplies. The blackened cups possess a slightly higher power of light-heat absorption than do the brown ones, but the latter have the advantage of retaining their color while the black coatings so far employed are rather easily removed, as by rain, etc. Until quite recently it has been impossible to obtain a black porous porcelain, though an attempt in this direction has been in progress for a number of years.

During hours of sunlight the dark cup gives off more water than the white one, assuming that both evaporate at the same rate in darkness. The radiant energy absorbed is converted (with or without passing through the phase of heating the water and cup wall) into the heat of vaporization of water. The dark cup becomes little if at all warmer than the white, at least in summer at Tucson, Arizona, where many of the tests of this new instrument have been carried out. Both cups are always considerably cooler than the air, which makes it evident that no absorbed heat is conducted outwardly from the cup. The difference in water loss from the two cups is thus an approximate measure of the difference between the amounts of radiant energy absorbed. This difference tells nothing definitely about the radiation *striking* the dark cup, no doubt some of the latter is reflected, but a much larger proportion is reflected from the white cup than from the dark one.

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[27] Livingston, B. E., A radio-atmometer for comparing light intensities. Plant World **14**: 96–99, 1911.

For studies in plant transpiration it was necessary to find out to what degree the dark atmometer behaves like plant foliage, when exposed to variations in sunlight intensity. Tests of this matter were carried out by exposing plants and instruments, standing side by side, to full sunshine and to various degrees of shade, for consecutive time intervals, and determining the transpirational losses from the plants and the evaporation from the instruments. The results[28] showed that the dark cup is affected in quite the same manner, qualitatively, as are plants, by changes in sunshine intensity. The radio-atmometer was thus established as a valuable instrument in studies of plant transpiration. It appears from the paper just cited that different plants are differently affected by variations in sunlight intensity, as was indeed to be expected, the power of absorbing solar radiation is thus shown to be an important physiological property of plants, a property requiring study before plant water relations can be logically analyzed.

The radio-atmometer is, then, an instrument for measuring the effectiveness of solar radiation as an accelerator of evaporation. This is exactly what its name implies. It has not been shown to be available for measuring solar radiation as a whole, though its readings no doubt approximate such measurements to a greater or smaller degree. It is further to be emphasized that this instrument gives no information as to the *quality* of the radiations received; it is only as energy (familiarly, as heat) that varying or differing intensities are to be studied by this means. Thus, as is shown in the paper last cited, actinometric measurements of solar intensity may be expected frequently to be in disagreement with those obtained by means of the radio-atmometer.

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[28] Livingston, B. E., Light intensity and transpiration. Bot. Gaz. **52**: 418-438, 1911.

Not the least important consideration in regard to the radio-atmometer is the fact that, like the atmometer itself, it is an automatically integrating instrument; if read hourly it gives the total effectiveness of absorbed radiation for each hour, if read weekly or monthly it gives weekly or monthly summations, etc.

*Standardization of Dark Cups.* The dark cups for the radio-atmometer are standardized in the same manner as are the white ones, only the standardization must never be carried out in sunlight. Ordinary diffuse daylight seems to be of too weak intensity sensibly to affect the water loss from the dark cup. From the nature of the case it will be seen that the corrected readings of a dark and of a white cup should be practically identical for the hours of darkness. At sunrise these two corrected values (of hourly readings, for example) begin to diverge, that from the dark cup becoming greater than the other, and they remain divergent throughout the day unless it is very dull. At sunset the two values again come together. The amount of divergence, for any hour, etc., is a measure of the intensity of solar radiations for that period, in so far as such radiation may accelerate evaporation from an imbibed surface.

With some preliminary work on the relation of rate divergence (of the two cups) to visible brightness of sunshine, the radio-atmometer should become available as a simple and exceedingly sensitive sunshine recorder.

*The Spherical Atmometer Cup.* It has been said that the cups for radio-atmometry must be placed at a certain angle with the vertical and that this angle must be altered every few days, with the advance of the season. It was at once obvious that such adjustment might be avoided through the use of spherical porous cups. Such cups, with a cylindrical neck projecting downward, for attachment to the water tubes, should present the same range of angle of incidence to the sun's rays at all times of the day and year; at all times during sunlight a hemisphere of surface must be illuminated. The obtaining of black and white spheres, of correct size, porosity, etc., was then, of prime importance for the development of radio-atmometry. For several years the writer has been endeavoring to have the requisite spheres manufactured and perfect ones have not yet been obtained. Quite independently, Prof. W. L. Tower,[23] of the University of Chicago, has obtained black and white spheres, which he has had in use for considerable time, with very satisfactory results. It is hoped that spherical porous cups may soon be placed upon the market. When this becomes possible, the development of the radio-atmometer should proceed rapidly.

With the advent of spherical cups a new standard will need to be adopted, for of course it will not be possible to establish a generally constant relation between the sphere and the cylindrical cup or between them and any water surface. As far as ordinary atmometry is involved, however, there appears no reason why the cylindrical cup may not be as satisfactory as the white sphere. It is only when radiation intensity is to be studied that spherical cups have any considerable advantage over the ordinary cylindrical type.

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[23] Announcement of Prof. W. L. Tower's work in: MacDougal, D. T., Annual report of the Director of the Department of Botanical Research. Year Book Carnegie Inst. Wash. **12**: 57–87. 1914. Page 71.

# BOOKS AND CURRENT LITERATURE

**Forest Climatology.**—A comparative study of climatic conditions in pine forest and in open natural "park" has been made by Pearson[1] at Fort Valley, at an elevation of 7200 feet in northern Arizona. Air and soil temperatures, humidity, evaporation, precipitation, and wind were measured at a station in the forest, one on the edge of the forest, and one in the park. Substantial differences in all of the climatic conditions except precipitation were discovered. There was a difference of 6.4° between the mean minimum temperatures of forest and park, the latter having the lower range. The mean maximum was about 1° higher in the park than in the forest. The thermometers in the park were $5\frac{1}{2}$ feet from the ground; a comparative set of readings taken 8 feet from the ground showed a mean minimum 2° higher, with nearly identical maxima. A comparison of minima in the forest and in a cut-over area of the same topographic situation, showed a mean about 2° lower in the clearing. These results are taken to indicate that radiation is partly responsible for the lower minima of the park, and that cold air drainage is also partly responsible for the difference. The mean summer temperature of the soil at a depth of 2 feet was about 5° higher in the park than in the forest. The mean humidity of summer was about 2.5% higher in the forest, and that of the winter about 4% higher in the park. The mean daily wind movement in all months was about twice as great in the park as in the forest. The evaporation at the edge of the forest was from 25 to 50% higher than in the forest. The other data for the edge of the forest are commonly midway between the values for the forest and the park. The influence of the described differences of climate on the fate of seedling pines was shown by planting two-year old trees in the forest and on the edge of the park. In the forest 90% survived, and on the edge of the park only 11% survived at the end of one month in the arid, windy season.

It is difficult to overestimate the importance of such work as Pearson's for the placing of silvicultural methods on a sound scientific basis. All problems in afforestation and many problems in reforestation have to be attacked on the basis of the physical conditions of open country rather than on those of a mature forest. Those who have only a text-book acquaintance with climatology, and recall the widely separated isothermal and isoanemic lines of the smoothly constructed maps, may find it difficult to realize that very considerable and very important differences of climate may exist within a stone's throw of each other on account of topography or dissimilar vegetations. The experienced forester knows that such is the case, and appreciates the value of a knowledge of these differences in handling the forests in such a manner as to secure the optimum reproduction. —FORREST SHREVE.

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[1] Pearson, G. A., A meteorological study of parks and timbered areas in the western yellow pine forests of Arizona and New Mexico. Mo. Weather Rev. **41**: 1615-1629. 1914.

REST PERIOD.—The occurrence of a rest period in plants has been the subject of an immense amount of investigation. During this rest period certain physical and chemical changes are continually going on which are essential to the release of the growth processes and to these changes is given the name "after-ripening." A survey of the literature on the underlying causes of this phenomenon reveals the presence of two widely diverse opinions one of which claims that the rest period is a direct response to changing external conditions and the other that it is the result of fixed, hereditary, internal causes. From a study of the rest period in potato tubers Appleman[2] has made some important contributions to our knowledge of this subject. He shows that the latter explanation is inadequate in that the rest period may be entirely eliminated. He was able to sprout potatoes at any time by removing the skins and supplying favorable conditions for growth. Sprouting in new potatoes may be stimulated by subdued light or by wrapping them in cotton saturated with hydrogen peroxide which is decomposed by catalase within the tubers. The rest period is therefore to be regarded as correlated with the supply of oxygen to the internal tissues which in nature is regulated by skin characters. That water absorption is not the prime factor is shown since tubers whose skins are removed will sprout even in dry storage much earlier than those whose skins are intact.

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[2] Appleman, C. O., Study of rest period in potato tubers. Md Agr. Exp. Sta. Bul. 183: 181–226, figs. 17. 1914. Physiological behavior of enzymes and carbohydrate transformations in after-ripening of the potato tuber. Bot. Gaz. **52**: 306–315. 1911. Changes in Irish potatoes during storage. Md. Agr. Exp. Sta. Bul. 167: 327–334. 1912.

Since respiration in stored potatoes becomes very weak just above the freezing point and there is consequently little conversion of starch and sugar this temperature is best suited for the storage of seed potatoes. After long exposure to this temperature sugar to the amount of 3 or 4% may have accumulated at the expense of the starch content. About four-fifths of this accumulated sugar may be converted back into starch after several days exposure of the tubers to a temperature of 70–75°F.—F. A. Wolf.

# NOTES AND COMMENT

Mr. A. G. Tansley, of Cambridge University, has recently distributed in collected form the papers which he has been contributing to The New Phytologist on the International Phytogeographic Excursion in the United States in the summer of 1913. These papers not only serve as a narrative of the Excursion but also afford a valuable sketch of the vegetation of the localities which it visited. The author speaks enthusiastically of "the overwhelming impressions of American landscapes and vegetation" which he received. He further states that one of the most vivid impressions he obtained in this country was of the earnestness and single-mindedness of American science.

Dr. Robert F. Griggs, of Ohio State University, has contributed a paper to the Bulletin of the American Geographical Society (March) on the effects produced by the eruption of the Alaskan volcano of Katmai on the vegetation of the surrounding region. The effect of the covering of ash has varied with its thickness and with the gradient of the slopes on which it fell. Trees were heavily loaded but have survived, alders in the near vicinity of the volcano suffered the loss of their leaves and young buds, and the herbaceous vegetation of bogs and tundra was completely covered, so that these areas now resemble sand plains and are in a condition such as to make their revegetation a slow process.

The papers submitted in competition for the prizes offered by THE PLANT WORLD, and announced in the April issue, will be judged by the following men: Dr. H. C. Cowles, Dr. B. M. Duggar, Prof. B. E. Livingston, Dr. D. T. MacDougal, Dr. J. B. Overton, Prof. G. J. Peirce, and Dr. H. M. Richards.

Macmillan and Company announce that they have in press, as one of their series of Science Monographs, a volume on The Mutation Factor in Evolution; with Particular Reference to *Oenothera*, by Dr. Reginald R. Gates.

# SOME REMARKS ON THE DESERT VEGETATION OF AMERICA

OVE PAULSEN

*Copenhagen, Denmark*

Having been asked by one of the leaders of the International Phytogeographical Excursion in America to publish a paper in THE PLANT WORLD I have pleasure in doing it indeed I would do a great deal more in order to show my gratitude for the great hospitality shown to me in America, and more especially for the admirable organization of the excursion and the heavy amount of work done by its conductors.

On the other hand, having no thorough knowledge of American vegetation I will restrict myself to some few remarks on the desert vegetation of America.

It was of the greatest interest to me to note the difference in vegetation as the party moved westward from the east American forests, in the drier parts of which oak has displaced beech, and to see in the proper order the succeeding vegetations: prairies, plains, sage brush. Some years ago I travelled through Russia to Transcaspia and saw the same succession: beech, oak, steppes, Artemisia plain, and then came the true desert in the hottest and driest regions. In America we hardly saw any desert so barren and desolate as those in Inner Asia, but what came nearest to it was the vegetation at Mecca, California.

Some members of the excursion argued that what was shown them as deserts were not deserts but different forms of steppes, many phytogeographers regarding all xerophytic and not too scattered vegetation as steppes. As I have dealt with this question elsewhere I shall not enter upon it here but shortly remark that, in my opinion, it is better to restrict the term steppe to that vegetation which is often called grass-steppe and which may, in short, be defined as a nearly closed vegetation of more or less xerophytic herbs, especially hemicryptophytes growing in a soil containing humus but no sulphides or chlorides, and where the moisture is greater in the upper layers.

This definition which is nearly in agreement with that of Schimper and of Tanfiljew, applies to the Great Plains in America, as we saw them at Akron, Colorado.

As deserts I would term plant formations the soil of which is devoid of humus or very poor in it and contains often sulphates or chlorides. The formations are very open and they frequently include trees and shrubs, which together with long-lived herbs are strongly adapted to drought. Spring-plants are numerous.

Desert thus defined includes, presumably, all that in America is called desert, from the sage brush plains to salt flats, sand deserts and the shrub and cactus desert in Arizona.

It is indeed a wide range for one term to cover, too wide for a scientific term. It might be regarded as a provisional term, and, as the different forms of desert become successively properly known and described, experience and comparison might teach one how to distinguish and how to term them scientifically.

The comparison could be made by aid of the system of growth-forms established by Raunkiaer. This distinction of growth-forms is based upon the degree of protection afforded to the buds which survive the unfavourable season of the year, this being the season which limits the distribution of plants.

Raunkiaer's system enables us to express statistical data for the different regions which can then be numerically compared by their "biological spectra." By this term is meant the percentage of the different growth-forms (biological types) of the region in question. By the making of a biological spectrum all species, rare or common, are alike in importance. On the other hand, in studying plant formations, Raunkiaer (1909) has made up a method by which firstly the species composing the formation are given a character in numerals indicating their frequency, and secondly the growth-forms get their statistics representing the rôle they play in the plant-society.

Had there been time enough the writer could perhaps have undertaken the task of trying to make some American desert statistics in the field after this scheme. Yet from complete plant-lists biological spectra can be made but there must necessarily be some mistakes as to the growth-forms to which the different species belong. In what follows an attempt will be made to construct biological spectra of the deserts we saw during the I. P. E. in America, but no attempt will be made to make statistics of the frequency of the growth-forms, as this work must be done in the field.

First it will be appropriate to define the biological types (growth-forms) established by Raunkiaer.

The Fanerophytes (trees and shrubs) constitute the first type, their dormant buds being attached to branches which project freely into the air. They are in a certain sense the least protected and accordingly are very dominant in countries where the conditions are always favourable (moist tropics).

The next group is the Chamaephytes, with their dormant buds situated on the surface of the soil or just above it (limit: 30 cm.). They include plants with above-ground creeping and persistent shoots, cushion-plants and undershrubs, the latter being conspicuous by the distal or apical parts of the shoots dying away during the unfavourable season.

Then follow the Hemicryptophytes which have their buds placed in the surface of the soil.

The Cryptophytes form the fourth group characterized by the dormant buds being subterranean or subaquatic. Aquatic plants have been omitted in this paper, only Geophytes are reckoned with.

The Therophytes or plants of the favourable season are the best protected, as they live through the unfavourable season as seeds; they are thus annual plants.

These groups are further subdivided but no use is made of the subdivisions here, as the writer is not well enough acquainted with American plants.

The procedure in making the biological spectra was this: The plants were listed, the growth-form for each plant was determined (partly in the herbarium of the Botanical Museum in Copenhagen, partly by aid of floras) and the letter representing the growth-form was written at the plant's name: F denotes Fanerophyte, Ch Chamaephyte, H Hemicryptophyte, G Geophyte, Th Therophyte. When each plant has got its letter, the types are counted up and their percentage is calculated.

The following plant-lists have been made use of:

1. For the plains at Akron, Colorado, the lists published by H. L. Shantz for the different plant-associations. He gives 79 species (Cryptogams excluded) which is, as he remarks himself, not a complete enumeration, but they will, I hope, constitute a fair representation as to growth-forms of the plants of the region.

2. The lists given by Kearney, Briggs, Shantz, McLane and Piemeisel for the different associations in the Tooele Valley, Utah. The lists include 116 species and are likely to be fairly exhaustive, as the authors have visited the place several times at different seasons.

3. Spalding's exhaustive list of Plants of the Desert Laboratory domain at Tucson, Arizona. Spalding gives (p. 104) statistics of what he calls "vegetation forms" of plants from different habitats, and from his table I have taken the numerals given for Tumamoc Hill and for the Mesa-like mountain slopes and added them together. Thus I have not taken into account the plants from the flood plain or from the irrigation ditches or introduced species. This I have done because the numerals must be comparable with those from Akron and Tooele where hygrophytes are not considered. Of Spalding's "vegetation forms" I have identified trees, shrubs, dwarf-shrubs and woody twiners with Fanerophytes, half shrubs with Chamaephytes, perennial and biennial herbs with Hemicryptophytes (and Geophytes) and annual herbs with Therophytes. This identification may not be right in all cases (especially with regard to Fanerophytes and Chamaephytes) but still I think I could hardly come nearer the truth than in this way, having no Arizona flora and only a scanty amount of herbarium material from that state.

4. In a similar manner I have used the analysis annexed to

Parish's catalogue of Salton Sink plants. Here, I have taken only the xerophytes, regarding trees and shrubs as Fanerophytes, "semi-shrubs" as Chamaephytes, "perennial herbs" as Hemicryptophytes and Geophytes and "annual herbs" as Therophytes.

The four biological spectra resulting are given in the table. To them is added the spectrum for Death Valley quoted from Raunkiaer (1908) who made it after Coville's catalogue of Death Valley plants, and further the "normal spectrum" is put down after Raunkiaer. This is the biological spectrum for 400 species taken at random from a list of the plants of the whole earth; it should accordingly be the biological spectrum of the whole earth.

|  | *Number of species* | *Percentage of species in each life-form* |  |  |  |  |
|---|---|---|---|---|---|---|
|  |  | F | Ch | H | G | Th |
| Akron | 79 |  | 19 | *58* | 8 | 15 |
| Tooele Valley | 116 | 2 | *23* | *46* | 3 | 14 |
| Tucson | 266 | 18 | 11 | 24 |  | *47* |
| Salton Sink | 81 | *33* | 6 | 14 |  | *47* |
| Death Valley[1] | 294 | *26* | 7 | 18 | 2 | *42* |
| Normal spectrum[2] | 400 | 47 | 9 | 27 | 3 | 13 |

[1] Five percent marsh-plants are not entered, accordingly the percentages given are a little too low.

[2] One percent marsh-plants are not entered.

From the table the following conclusions can be drawn:

1. The plains at Akron are characterized by Hemicryptophytes which constitute more than half of all the species. Chamaephytes are also common, at least compared with the normal spectrum. Therophytes keep to the level of the normal spectrum.

2. Tooele has still many Hemicryptophytes, but next to them come the Chamaephytes, which are indeed very conspicuous in Utah. There are two Fanerophytes only (*Sarcobatus* and *Juniperus*), and Therophytes are as in Akron.

3. In Tucson the Hemicryptophytes have decreased under the percentage of the normal spectrum so that this region is

not characterised by them as is Akron. Here, in Tucson, Therophytes are very prominent, and the Fanerophytes are rather numerous.

4. Salton Sink is like Tucson, the only difference being that Fanerophytes have increased at the cost of Hemicryptophytes being still under the percentage of the normal spectrum. Death Valley shows the same features.

Summing up, we find three distinctly different types of plant-communities namely:

Hemicryptophytic: The Colorado plains.

Chamaephytic: The Utah desert.

Therophytic: The Tucson, Salton and Death Valley deserts.

The yearly precipitation of Akron, Tooele and Tucson is respectively 47, 40, and 27 cm.,[1] of Salton hardly over 20 cm. So we find a coincidence of drier climate with development of other growth-forms: Hemicryptophytes give way to Chamaephytes and these to Therophytes and partly Fanerophytes.

In the old world we have at least partly a parallel transition: in Southern Russia Hemicryptophytes dominate (the government of Jekaterinoslaw has 55%), and in Transcaspia Therophytes preponderate (41%); as to Fanerophytes the percentage of the two regions is respectively 5 and 11%. Thus also here there is a parallelism. The interjacent Chamaephyte region has not been numerically demonstrated in the old world, yet we know that in the countries between Southern Russia and Transcaspia proper waste regions are covered with a vegetation of Artemisias and similar plants. So we may be justified in believing that the Chamaephyte region is there.

Finally it should be emphasized that the material upon which my conclusions are based is not complete and that if perfect biological spectra could be made they would without doubt give a more vivid and detailed picture of the relations between plains and different deserts in America. Yet I hope that there are no fatal errors in the preceding remarks.

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[1] Quoted from Kearney, Briggs, Shantz, McLane and Piemeisel and from Briggs and Belz.

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# THE ANTIZYMOTIC ACTION OF A HARMFUL SOIL CONSTITUENT: SALICYLIC ALDEHYDE AND MANNITE

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In an investigation of the soils on the Mount Vernon estate, Virginia, several organic compounds were isolated and identified[1] in a sample taken in the flower garden from among the box hedges. Two of the compounds isolated are salicylic aldehyde $C_6H_4.OH.COH$ and mannite $C_6H_{14}O_6$. The effect of these compounds on growth have been studied. The salicylic aldehyde has proven to be very harmful to plants, grown in nutrient solutions, in soils in pots and in the field.[2]

The subject of this paper is concerned with the effect of mannite on growth and the circumstances under which it exists in soils. This sugar alcohol was found in the Mount Vernon soil in an amount of about 500 lbs. per acre. Mannite can readily be produced by certain soil fungi, yet it is remarkable that it can persist in soils for it is a very unstable compound, being an excellent medium for the development of bacteria. Its effect on growth was studied in the green-house and some indications of its physiological action obtained but no very definite results were secured, because of the fact that the mannite solutions with the fertilizer salts were good media for the development of bacteria.

The tests were made by growing wheat seedlings in distilled water culture and in nutrient solutions. Ten plants were grown in each bottle holding 250 cc. of solution. The seedlings were supported in a notched cork which fitted closely in the wide mouth bottle. The first experiment was made using mannite dissolved in pure distilled water, as a culture solution. The mannite was used in concentrations of 10 to 200 parts per million, and the plants were grown in the solutions from January 12–25. Growth in some of the mannite concentrations was about equal to that in pure distilled water, some of the cultures produced larger growth and others made less growth than in distilled water.

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[1] Shorey, E. C., Some organic soil constituents. Bull. 88, Bureau of Soils, U. S. Dept. Agric. (1913).

[2] Schreiner, O. and Skinner, J. J., Harmful effects of aldehydes in soils, Bull. 108, U. S. Dept. Agric. (1914).

A large experiment was made using nutrient solutions composed of calcium acid phosphate, sodium nitrate, and potassium sulphate. These salts were used in solution singly, in combination of two, and of three salts, in all possible proportions, varying in 10 % stages. In this set there were 66 solutions, which were used as a control and to a second set of 66 solutions similar in composition was added 100 p.p.m. of mannite. The composition of each of the 66 solutions is given in the second, third and fourth column of table 1. Wheat plants grew in these solutions from February 14 to February 26. The solutions were changed every third day and replaced by fresh solutions of the same composition. These solutions were analyzed for nitrate after the plants had grown in them. They were also tested for nitrites and ammonia, to determine if decomposition was going on. In table 1 are given the composition of the culture solutions together with the green weight produced in the solutions without mannite and with 100 p.p.m. of mannite.

The total weight produced in the 66 solutions without mannite was 151.2 grams against 142.4 grams for the cultures containing mannite. While the total growth was less in the mannite cultures than in the control solutions, a close examination of the table shows that in those solutions containing no phosphate, Nos. 56 to 66, the growth was larger in the mannite solution, with the exception of one, No. 56, than the control solutions. The mannite caused less growth in nearly all of the other cultures which contain phosphate in some amount. Among the 46 solutions containing phosphate only ten of the mannite solution produced larger growth than their checks. The roots of the

TABLE 1

*Effect of mannite on wheat in nutrient solutions composed of calcium phosphate, sodium nitrate and potassium sulphate*

| CULTURE No. | COMPOSITION OF CULTURE SOLUTION | | | [illegible] | [illegible] | CULTURE No. | COMPOSITION OF CULTURE SOLUTION | | | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_2O_5$ | $NH_3$ | $K_2O$ | | | | $P_2O_5$ | $NH_3$ | $K_2O$ | | |
| | | | | | | | p. p. m. | | | grams | |
| 1 | 80 | 0 | 0 | 1.10 | 0.97 | 34 | 24 | 40 | 16 | 3.06 | 2.60 |
| 2 | 72 | 0 | 8 | 1.30 | 1.30 | 35 | 24 | 48 | 8 | 2.18 | 2.43 |
| 3 | 72 | 8 | 0 | 1.31 | 1.30 | 36 | 24 | 56 | 0 | 1.85 | 1.74 |
| 4 | 64 | 0 | 16 | 1.40 | 1.36 | 37 | 16 | 0 | 64 | 1.45 | 1.30 |
| 5 | 64 | 8 | 8 | 2.02 | 1.80 | 38 | 16 | 8 | 56 | 2.68 | 2.03 |
| 6 | 64 | 16 | 0 | 1.27 | 1.32 | 39 | 16 | 16 | 48 | 2.61 | 2.58 |
| 7 | 56 | 0 | 24 | 1.41 | 1.43 | 40 | 16 | 24 | 40 | 3.45 | 2.26 |
| 8 | 56 | 8 | 16 | 2.44 | 1.74 | 41 | 16 | 32 | 32 | 3.02 | 2.56 |
| 9 | 56 | 16 | 8 | 2.10 | 2.04 | 42 | 16 | 40 | 24 | 3.18 | 2.70 |
| 10 | 56 | 24 | 0 | 1.71 | 1.50 | 43 | 16 | 48 | 16 | 2.77 | 2.87 |
| 11 | 48 | 0 | 32 | 1.56 | 1.59 | 44 | 16 | 56 | 8 | 2.57 | 2.45 |
| 12 | 48 | 8 | 24 | 2.45 | 2.32 | 45 | 16 | 64 | 0 | 1.75 | 1.46 |
| 13 | 48 | 16 | 16 | 2.55 | 2.50 | 46 | 8 | 0 | 72 | 1.49 | 1.55 |
| 14 | 48 | 24 | 8 | 2.26 | 2.01 | 47 | 8 | 8 | 64 | 2.70 | 1.92 |
| 15 | 48 | 32 | 0 | 1.62 | 1.61 | 48 | 8 | 16 | 56 | 3.05 | 2.98 |
| 16 | 40 | 0 | 40 | 1.77 | 1.55 | 49 | 8 | 24 | 48 | 2.92 | 2.47 |
| 17 | 40 | 8 | 32 | 2.88 | 2.58 | 50 | 8 | 32 | 40 | 2.80 | 3.33 |
| 18 | 40 | 16 | 24 | 2.90 | 2.47 | 51 | 8 | 40 | 32 | 2.03 | 3.11 |
| 19 | 40 | 24 | 16 | 2.51 | 2.40 | 52 | 8 | 48 | 24 | 3.12 | 3.03 |
| 20 | 40 | 32 | 8 | 2.26 | 2.17 | 53 | 8 | 56 | 16 | 3.00 | 2.57 |
| 21 | 40 | 40 | 0 | 1.50 | 1.60 | 54 | 8 | 64 | 8 | 2.57 | 2.46 |
| 22 | 32 | 0 | 48 | 1.58 | 1.39 | 55 | 8 | 72 | 0 | 1.72 | 1.61 |
| 23 | 32 | 8 | 40 | 3.29 | 1.81 | 56 | 0 | 0 | 80 | 1.30 | 1.22 |
| 24 | 32 | 16 | 32 | 2.60 | 2.63 | 57 | 0 | 8 | 72 | 2.08 | 2.29 |
| 25 | 32 | 24 | 24 | 3.20 | 2.54 | 58 | 0 | 16 | 64 | 2.37 | 2.62 |
| 26 | 32 | 32 | 16 | 2.46 | 2.52 | 59 | 0 | 24 | 56 | 2.38 | 2.72 |
| 27 | 32 | 40 | 8 | 2.07 | 2.17 | 60 | 0 | 32 | 48 | 2.60 | 2.68 |
| 28 | 32 | 48 | 0 | 1.66 | 1.63 | 61 | 0 | 40 | 40 | 2.43 | 2.60 |
| 29 | 24 | 0 | 56 | 1.32 | 1.66 | 62 | 0 | 48 | 32 | 2.33 | 2.65 |
| 30 | 24 | 8 | 48 | 2.88 | 2.58 | 63 | 0 | 56 | 24 | 2.30 | 2.33 |
| 31 | 24 | 16 | 40 | 3.29 | 2.63 | 64 | 0 | 64 | 16 | 2.28 | 2.32 |
| 32 | 24 | 24 | 32 | 2.89 | 2.00 | 65 | 0 | 72 | 8 | 2.00 | 2.05 |
| 33 | 24 | 32 | 24 | 3.23 | 3.07 | 66 | 0 | 80 | 0 | 1.58 | 1.80 |

plants in the no phosphate cultures containing mannite were healthy and clean and fully as good as the control cultures, while the root growth in the mannite solutions which contain phosphate, were unhealthy and short and made a poor growth.

When the solutions had grown plants for three days they were replaced by new solutions and the old solutions analyzed. More nitrates had disappeared in the set of solutions containing mannite than in the control set of solutions. In the mannite cultures nitrite and ammonia were detected in solutions Nos. 1 to 46. The amount of nitrite varied from 6 to 10 parts per million, and each culture gave a good test for ammonia. There was no nitrite or ammonia in the mannite solutions Nos. 56 to 66 which contained no phosphate. The set of nutrient solutions containing no mannite, and used as a control, contained no nitrites or ammonia, nor have they ever been observed in these control sets.[3]

These data show that the mannite in the nutrient solutions containing all three of the nutrient elements, underwent decomposition, there was a formation of nitrites and ammonia, and that consequently the decomposition caused poor plant growth. The solutions in which there was no phosphate was not a good medium for the development of bacteria, consequently there was no decomposition of the mannite. Mannite as such does not seem to be harmful to wheat seedlings, and when decomposition does not take place the material would seem to be used by the plants and an increased growth results.

In view of the fact that the Mount Vernon soil was found to contain both salicylic aldehyde and mannite, an experiment in nutrient solutions was planned and conducted in which both these substances were added to the culture solution.

In this experiment the nutrient solution contained calcium acid phosphate, sodium nitrate and potassium sulphate in amounts of 16-32-32 p.p.m. of the fertilizer constituents $P_2O_5$, $NH_3$ and $K_2O$. Mannite was added in amounts of 100 p.p.m. and the salicylic aldehyde added, varied in the different solutions, from

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[3] Schreiner, O. and Skinner, J. J., Nitrogenous soil constituents and their bearing on soil fertility. Bull. 87, Bureau of Soils, U. S. Dept. Agric. (1912).

1 to 100 parts per million. Duplicate sets of these cultures were prepared, in one set plants were grown and in the second set the bottles containing the solutions were allowed to stand. At the end of three days the solutions were analyzed for nitrates, nitrites and ammonia. This was done every three days, until the plants had grown twelve days. The results of the analysis after the plants had grown the first three days, and the final green weight of the plants grown in each solution are given in table 2.

TABLE 2

*Effect of salicylic aldehyde in preventing decomposition in mannite solutions*

| [illegible] | TREATMENT | [illegible] | COMPOSITION OF SOLUTIONS AFTER 3 DAYS | | | | | | GREEN WEIGHT OF PLANTS |
|---|---|---|---|---|---|---|---|---|---|
| | | | Without plants | | | With growing plants | | | |
| | | | $NO_3$ | $NO_2$ | $NH_3$ | $NO_3$ | $NO_2$ | $NH_3$ | |
| | | p.p.m. | p.p.m. | p.p.m. | p.p.m. | p.p.m. | p.p.m. | p.p.m. | grams |
| 1 | Nutrient sol + 100 p.p.m. mannite | 117 | 83.4 | 20.0 | Trace | 40.0 | 22.2 | Trace | 2.75 |
| 2 | Nutrient sol + 100 p.p.m. mannite | 117 | 82.0 | 23.0 | Trace | 16.6 | 22.2 | Trace | 2.80 |
| 3 | Same + 1 p.p.m. salicylic aldehyde | 117 | 50.0 | 40.0 | Trace | 30.0 | 20.0 | Trace | 2.35 |
| 4 | Same + 5 p.p.m. salicylic aldehyde | 117 | 100.0 | 26.6 | Trace | 60.0 | 14.2 | Trace | 2.20 |
| 5 | Same + 10 p.p.m. salicylic aldehyde | 117 | 115.0 | 2.5 | None | 90.8 | 6.6 | Trace | 1.87 |
| 6 | Same + 25 p.p.m. salicylic aldehyde | 117 | 115.0 | None | None | 111.0 | 3.5 | None | 0.93 |
| 7 | Same + 50 p.p.m. salicylic aldehyde | 117 | 118.0 | None | None | 111.0 | None | None | 0.56 |
| 8 | Same + 100 p.p.m. salicylic aldehyde | 117 | 118.0 | None | None | 111.0 | None | None | 0.38 |

An examination of the tables shows that nitrites and ammonia formed in the duplicate mannite solutions Nos. 1 and 2 and in those solutions which contained mannite together with 1, 5 and 10 parts per million of salicylic aldehyde. In the solutions which had no plants 25 p.p.m. and more of salicylic aldehyde prevented any decomposition in the solution. In the solutions with plants it required as much as 50 p.p.m. of salicylic aldehyde in the mannite solutions to prevent decomposition. Other sets of solutions similar to these were analyzed, and the results were substantiated. In every case 25 to 50 parts per million of salicylic aldehyde in nutrient solution with mannite prevented any bacterial action. The green weight of the plants grown in one set of the solutions is given in the last column of the table. It is again seen here, that the salicylic aldehyde is harmful to growth of plants as well as to bacterial life.

The existence of mannite in the Mount Vernon garden soil is probably made possible by the simultaneous presence of salicylic aldehyde. Without any antiseptic action of this kind, mannite, if formed, would immediately be destroyed by soil organisms and probably could not exist as such for any length of time.

This garden soil has grown box hedges, roses, and other perennial garden plants for years and manure has been liberally applied. The subsoil is of such a nature as to prevent the proper movement of air and moisture. An examination of the soil in the laboratory showed that the surface soil was acid and the sub-soil decidedly so. The growth of the garden plants had become poor, and they showed signs of going backward in certain locations.

As a result of the laboratory examination lime and phosphatic fertilizer were applied and provision made for better drainage so that moisture and air may better circulate, and better results have been secured. Data have been secured in this laboratory which show that the harmful effects of aldehyde on plants is partly overcome by lime and by phosphates. When conditions in the soil are such as to change or destroy the harmful compound salicylic aldehyde, soil organisms and other natural processes of the soil would prevent the formation or destroy immediately after formation such an unstable compound as mannite.

# BOOKS AND CURRENT LITERATURE

A Montane Rain-Forest.—Graphic descriptions of characteristic plant formations are always welcome and stand out in pleasing contrast to mere lists of species masquerading as ecological studies. Especially are such descriptions of importance where the communities dealt with are truly virgin; indeed, the correct delineation of the fast vanishing primitive vegetation of the earth is the most urgent phytogeographical work at the present time. Shreve, in his recent book, A Montane Rain-Forest,[1] has supplied a notable contribution in this regard. But he has done more than this, for the scope of his work is well indicated by its supplementary title, A Contribution to the Physiological Plant Geography of Jamaica.

The forest treated of is situated on the Blue Mountains of Jamaica at an altitude of 4500 feet to 7428 feet. The climate of this area has a yearly rainfall of 105 inches to 168 inches, 172.4 rainy days and an annual mean temperature of 60.8°F.; frost is virtually unknown. The forest itself is in part temperate in character both in its ecological and floristic composition, and evidently resembles in no small degree the lowland rain-forest of New Zealand, though this latter, strange to say, appears to bear ecologically a more pronounced tropical stamp. This striking resemblance between a tropical and a temperate plant formation is emphasized by several of the fine photographs that add greatly to the value of the book. Plate 1, with its wealth of ferns and Plate 8 with the pendant moss draping the slender, straggling tree-trunks, recall exactly typical scenes in New Zealand rain-forest, not only of the warmer parts but even where the climate is of a semi-subantarctic character.

After dealing with the physical features and climate of the area, the author gives a list of the characteristic species of the florula, citing 270, of which no fewer than 93 are pteridophyta. In New Zealand, at a generous estimate, no piece of forest would contain more than 212 species, of which about 65 would be ferns and lycopods. Next comes a clear account of the physiognomy of the forest, its ecological characteristics and a classification of the vegetation according to distinctions in habitats, such differences arising from position with regard to sun and the prevailing wind, the highly dissected erosion topography and altitude. Work of this kind is considered by Warming as not difficult, and in comparison with some of the problems presented by plant ecology which seem almost impossible to solve this is true enough, but it is nevertheless far from an easy matter to paint an accurate word-picture of a complicated closed association or to properly appreciate and keep in their proper place the facts of observation when quite minor distinctions may be of crucial importance. Above all, any account of a plant formation loses half its value if it cannot be readily used for purposes of comparison with related formations in other regions. In this latter regard the author has succeeded in no small degree, so that it is quite easy for one acquainted with a New Zealand rain-forest to see wherein lie its resemblances to that of montane Jamaica or its differences therefrom.

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[1] Shreve, Forrest, A Montane Rain-Forest: A Contribution to the Physiological Plant Geography of Jamaica. Carnegie Inst. Wash. Publ. 199. Pp. 110. pls. 29, figs. 18. 1914.

The vegetation of ravines and ridges presents in a most striking manner the effects of erosion topography, that of the former being strongly hygrophilous and of the latter almost xerophilous. So, too, in certain New Zealand forests a ravine will contain hygrophilous rain-forest and the ridge subxerophilous *Nothofagus Solanderi* forest, this an altogether different formation.

Epiphytes are a most important group in this Jamaican forest, every type being represented, but on the other hand lianes, so much in evidence in New Zealand, are not numerous. The epiphytes show a zonal distribution in harmony with the moisture conditions, so that the most hygrophilous occupy positions near the ground, midway come those that can tolerate an occasional scarcity of water, while in the forest roof xerophytes flourish. These latter differ from those of a similar station in New Zealand in that there is only one large plant, *Caraguata sintenesii* (Bromeliaceae), whereas in New Zealand this species is represented by the epharmonically similar *Astelia Solandri* (Liliaceae), while various spreading shrubs several feet in height are also present. Possibly the most remarkable fact about these epiphytes is the physiological capacity of certain Hymenophyllaceae to tide over considerable periods of drought, whereas others of apparently identical structure die rapidly in the absence of sufficient water.

From the standpoint of general ecology, the concluding portion of the book is of especial moment, dealing as it does with the [illegible] portion of rain-forest plants based on actual experiment. For the purpose of this valuable research a number of plants were selected, including two of the commonest trees, a common shrub, a thick-leaved herb, two herbs of the forest floor and two extremely hygrophilous ferns. Without going into details here, the author found that the rates of relative transpiration of the rain-forest plants dealt with and those of certain xerophytes of the Arizona desert are of the same order of magnitude, *i.e.* the rates of transpiration in the two regions are proportional to the rates of evaporation that prevail in them. While the plants of the rain-forest are capable of losing much more water per unit area than are those of the desert when the two kinds of plants are exposed to identical conditions, yet as each set exists in its habitat, the desert plant loses far more water per unit area than does the forest plant. This, though in line with certain recent publications, is contrary to the accepted opinion which is based not on experiment but on a consideration of the reduced transpiring surface of desert plants.

One is apt to look upon rain-forest as a purely hygrophilous formation in which xerophytes have no place. This the author rightly shows to be a false conception. "There is no type of vegetation," he declares, "in which may be found a wider diversity of life forms than exist side by side in a tropical montane rain-forest. Together with the structural diversities discoverable in the field or at the microscope, are diversities of physiological behavior, discoverable by observation or experiment, and sometimes correlated with the structural features. There are quite as high degrees of specialization to be found in the rain-forest as may be sought in the desert."

Much more could be extracted with profit from Shreve's admirable book, the chief fault of which lies in its brevity. One would have welcomed, for instance, a special account of the growth forms accompanied by statistics for comparative purposes. Ecological works, with few exceptions, seem to take it for granted that the reader is acquainted with the species cited, whereas he frequently knows but little regarding them, and even if assisted by a flora may get far astray—L. COCKAYNE, WELLINGTON, NEW ZEALAND.

PLANT BREEDING.—In 1895, Bailey incorporated some excerpts from the writings of Verlot, Carrière and Focke with three of his own lectures relating to the improvement of plants and published the material under the title Plant Breeding. The author's reputation as the leading American agricultural botanist together with his charming literary style carried the volume through three editions and several reprints during the next ten years, although it did not have the intrinsic value of most of his other works. It was a compendium of opinions which were often unsupported by facts; nothing in it was very helpful, nothing very wrong. One laid it down with no distinct idea of having read anything positive relating to plant breeding.

In 1906, with the appearance of a fourth edition, there was a decided change in form. The author had sublet various parts. This entailed a sacrifice of style and unity; but there was a gain in facts—an inclination toward practicability and usefulness probably due to the guiding hand of Webber.

In the present edition,[1] the valuable qualities of both types of the earlier imprints have been retained. There is unity of purpose through the efforts of one reviser, Dr. Gilbert; there is the old simplicity of style through the supervision of Dr. Bailey. The book is now really an introduction to scientific plant breeding, and as such will doubtless be of very great interest to the many laymen who wish to become conversant with modern ideas of plant improvement. It can also be heartily recommended as a text book for classes in general plant breeding in agricultural colleges if used with discretion by a teacher with some first hand knowledge of the subject and if supplemented by other works. It is not of a sufficiently advanced character, however, to be used for serious instruction in genetics.

The first few chapters deal with variation in much the same hazy way that characterized the earlier editions. While no doubt the beginning student may gain something from them it is to be regretted that some of the numerous recent discoveries relating to reproduction, development and variation are not given as a foundation upon which the remainder of the discussions could be placed. There follows a brief discussion of statistical methods in Chapter IV and a *résumé* of DeVries' facts and philosophy regarding mutations in Chapter V. The brief treatment of biometry is good, though there are several typographical errors and a certain vagueness concerning the meaning of probable errors. The reviewer suggests that in future editions, the chapter be placed in an appendix. The mutation theory is treated wholly from the DeVriesian standpoint of 1903. Possibly the account would have had a somewhat greater value if a description of the more important modern researches on the subject had been incorporated.

[1] Bailey, L. H., Plant Breeding. Fifth Edition, revised by A. W. Gilbert. Pp. 474, figs. 113. The Macmillan Company, New York, 1914 ($2.00).

Chapter VI, on hybridization, includes many things. There are discussions of natural selection, limits of crossing, natural hybrids, artificial hybrids, effects of inbreeding and crossbreeding, and graft hybrids. As indicated, it is a dip here and a dip there into some of the most important questions of plant breeding, with hardly an adequate treatment of each phase. Heredity, in the next chapter of sixty pages, is dealt with more ably, though one may be skeptical as to the desirability of continuing to use the coefficient of correlation, a measure of somatic resemblance, as a test of heredity after the confusion it has led to through the efforts of the English biometrical school. Furthermore, the reviewer feels that the beginning student may get an erroneous idea of Mendelian inheritance, or rather of the meaning of the Mendelian notation, from the author's method of treating the subject. Presumably, the very literal interpretation of a plant as a unit character mosaic is due to the need to compress a large amount of material into a small space, but it might work considerable harm.

Perhaps the best chapter in the volume is that on How Domestic Varieties Originate (Chapter VIII). It contains much historical matter that would be difficult to obtain elsewhere.

The remainder of the book is much like the fourth edition. It deals with the technique of crossing and "the forward movement in plant breeding" as illustrated by practical work in various parts of the world.

There are five appendices, including a glossary, a list of plant breeding books, a bibliography brought up to date (from 1905, the year of the last citations in the fourth edition), and a series of laboratory exercises. The bibliography is especially valuable, though one notices that many important foreign publications are omitted. The definitions given in the glossary for such terms as allelomorph, dominant character, factor hypothesis, and segregation, will hardly be accepted by geneticists.—E. M. East.

PHOTOTROPISM (?) OF UREDINIOSPORE GERM-TUBES.—A short paper by Fromme[1] presents the newly-demonstrated fact that urediniospores of *Puccinia rhamni*, and their young germ-tubes, are sensitive to one-sided illumination. The large majority of these spores, when germinating with one-sided lighting, protrude the germ-tube from a spire on the shaded side. If a tube protrudes from the more strongly lighted portion of the spore wall it almost always bends very soon, so that its tip becomes directed away from the source of light. The process of germination is thus apparently related to differences in light intensity on the different sides of the spore, and the young tubes are, at least apparently, negatively phototropic.

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[1] Fromme, F. D., Negative heliotropism of urediniospore germ-tubes. Amer. Jour. Bot. 2: 82–85. 1915.

The evidence presented seems to the reviewer to indicate an orientation of growth activity with reference to different intensities of the impinging light received by different portions of the surface of the spore or filament; these reactions are not apparently related directly to the *direction* of the light propagation. This somewhat important distinction is not considered by the author.

The purpose of this note is to emphasize the question that at once arises to the reader, whether the reactions here described are to be considered as related to light at all. May they not be due to asymmetrical heat or moisture conditions? Fromme's spores germinated on an imbibed substratum (gelatin) exposed in a moist chamber, and a small beam of diffuse daylight was allowed to fall upon the spores from one side and from somewhat above the level of the substratum. It is obvious that a light reaction may be involved in the behavior of the germinating spores, but it seems just as obvious that moisture and heat relations are here to be considered. The author does not take up this consideration at all, though he does remark: "That positive hydrotropism may partially explain stomatal entrance [of such hyphae, as germination occurs on leaves] is suggested by the work of Balls and Fulton but it is doubtful that this can be a factor of primary importance."

There appear to be about four logical possibilities here involved. (1) Light intensity may be the controlling asymmetrical condition and one-sided photochemical alterations within the cell may be the internal control of the reaction. This seems to be the interpretation adopted by the author. (2) The direction of the impinging light may be the important external condition; as has been remarked, this seems improbable from the data given, and it needs no more than mention here. (3) A temperature difference between the shaded side of the spore or filament and the illuminated side may bring about the observed orientation. Here we meet with several possibilities. (3a) The illuminated side receives more radiant energy and should therefore be warmer. (3b) The air of the moist chamber may be warmer on the illuminated side, so that that side of a cell may be warmed by conduction. (3c) Convection currents in the air about the cell, brought about by asymmetrical income of heat from the more distant surroundings, may render *either* the illuminated or the shaded side warmer than the other. Which side might be warmer cannot be foretold, under such conditions as are here considered, without detailed knowledge of these currents. (3d) Differences in the evaporation rate from shaded and lighted portions of the air-exposed surface may cause temperature differences in several ways; these possibilities need not be further analyzed. (4) Finally, differences in the moisture content of the cell-wall, on the illuminated and shaded sides, may produce the observed reactions as hydrotropic responses. The lighted side should be somewhat drier than the other side, whatever may be its temperature condition. If one of two like water-imbibed surfaces receives radiant energy and the other does not, it is quite possible for the former to evaporate more water than the latter, even though the other conditions may make the former the cooler of the two. It may be added that differences in moisture content between the two sides of the cell need not be postulated as a result of greater evaporation from one side; the moisture *content* of all the portions of the cell may remain alike, but the movement of water through the cell (from absorbing to transpiring surface) may bring about chemical differences between two regions of the protoplasm.

It seems highly probable to the reviewer that the author's interpretation is the correct one, but the experimental evidence seems to be no more in its favor than in favor of any one of several other possible interpretations, some of the most obvious of which have been mentioned in the incomplete logical analysis that has just been outlined. There is no doubt at all that these organisms do respond to one-sided illumination by diffused daylight, under the other conditions of Fromme's experiments; whether they respond *directly* to the light influence has not been investigated.—B. E. LIVINGSTON.

TRENT FOREST SURVEY.—Eighty years ago the Canadian government started work upon the Trent Canal, which was to provide a waterway connecting Lake Ontario and Georgian Bay, and to aid in opening up the immense pine forests of that part of Ontario. The numerous lakes and rivers of the region were to be utilized in the project. The work was carried on irregularly, abandoned and begun again many times, and even today is far from completion. In the meantime exploitation of the pineries outran the development of the canal. The forests were cut clean and burned over many times, so that the canal itself was frequently damaged by the resulting floods. In spite of the deterioration of the region, the great sum already expended ($10,000,000) would alone justify an attempt at conservation of what resources remain and improvement of present conditions. The Commission of Conservation of Canada therefore authorized the investigation by Dr. Howe and Mr. White.[1]

Dr. Howe reports upon the forest conditions of the region: that the forests types number four: (1) hardwood type (beech-maple); (2) mixed hardwood-conifer type; (3) conifer type (white pine, hemlock, or swamp conifer); (4) poplar-birch type (on burned over lands, and at present by far the most extensive). The relations of these forest types to soils and to each other are those that have been described for other portions of the transitional belt between Northeastern Conifer and Eastern Deciduous Forests.

The recommendations for methods of conservation and recuperation are as follows: (1) abandonment of all attempts at agriculture, as the region is thoroughly unsuited to such use; (2) careful protection of the region from fire, by governmental ownership of the watersheds, which would result in the growth of a timber crop (hardwoods, especially pulpwood—the pines are doomed), and the prevention of destructive floods; (3) encouragement of local industries such as the manufacture of small woodenware, utilizing the canal for transportation, and the abundant water power which is awaiting development.

Dr. Howe has been commissioned to make further investigations of the possibilities of future forest development. WILLIAM S. COOPER.

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[1] Howe, C. D., and White, J. H., Trent Watershed Survey. Pp. 156. Commission of Conservation, Canada. The Bryant Press, Toronto, 1913.

# NOTES AND COMMENTS

Dr. Eduard Rübel has recently called attention (Journal of Ecology, December 1914) to the confusion that has arisen in plant geography through the use of popular names for the designation of important plant communities. The words macchia, garigue, tomillares, and phrygana, for example, are shown to be used in different parts of southern Europe for vegetations that are closely similar, while such terms as heath and steppe are applied to very unlike plant communities. The action of the Brussels Congress in voting to retain these and other vernacular names in the technical terminology of plant geography has raised many voices in dissent. The plant geographers of the world are pre-eminently a body of men who can rise above any national bias in favor of the terms that have originated in their own particular language. There is no reason whatever for laying any weight on the matter of priority in seeking a rational and acceptable system of nomenclature for plant communities. We have perpetually before us the spectacle of taxonomy, devoutly sworn to the principle of priority, and thereby chained to the imperfect type specimens, the incomplete knowledge and the false judgment of a century or more ago. There is no valid reason why plant geographers should not arbitrarily create a system of naming for vegetational groups,—a system that would be international, logically complete, and authoritative through general agreement, without being inflexible or so sacrosanct that it could not be abolished whenever it was desirable to do so. Just such a scheme of nomenclature was proposed by Brockmann-Jerosch and Rübel in their Einteilung der Pflanzengesellschaften nach Ökologisch-Physiognomischen Gesichtspunkten, of which an English edition is now in preparation. There is much to be said in favor of the use of such a system, and the matter deserves careful consideration at the hands of plant geographers, and the fullest possible discussion. If by the adoption of such a system it should become possible to eliminate all further discussions of nomenclatorial matters in plant geography and ecology, and if the energy that has gone into them heretofore could be liberated and directed to some of the fundamental problems in these lines of work, the occasion would be one for profound congratulation.

Dr. H. C. Cowles and Dr. J. G. Coulter have issued a small manual of the spring flora of the north central and northeastern states (American Book Company). The book has been adapted to high school use by the omission of grasses and other difficult groups, and by the prefixing of a very simple analytical key. Trees, shrubs, and other plants of importance in ecological work have been included, and are described and illustrated in their spring condition.

Mr. B. C. Wallis has made a study of the rainfall conditions of the southeastern states in relation to the production of the cotton crop (Scottish Geographical Magazine, February, 1915). Cotton is grown in localities which vary in annual rainfall from 54 inches at the east to 31 inches at the west, but the crop is timed in such a manner that the precipitation during the growth of the cotton plant varies only from 17 inches in Texas to 23 inches in Florida.

The Monthly Weather Review for October 1914 contains a paper by Prof. W. J. Humphreys on frost protection, a paper by Prof. C. F. Marvin on the principles of air drainage, and several articles that describe the methods and results of extensive efforts that are made for the protection of orchards from frost in California, Ohio and other states.

# VEGETATION OF THE BRAZOS CANYON, NEW MEXICO[1]

PAUL C. STANDLEY

*National Museum, Washington, D. C.*

During August and September, 1914, Mr. H. C. Bollman and the writer camped for four weeks along the Brazos River, near the mouth of Brazos Canyon, in Rio Arriba County, New Mexico, some thirty miles south of the Colorado line. A large collection of plants was secured, and a general study of the vegetation was made, some of the results of which are stated here.

The Canyon is reached from the railroad at Chama, New Mexico, twenty-two miles distant on the Denver and Rio Grande Railroad. The narrow gauge line starting from Alamosa, Colorado, runs southwestward across the plains to Antonito, then turns westward and begins a gradual ascent of the southern spurs of the San Juan Mountains. The adjacent plains are covered chiefly with sagebrush, rabbit-brush (*Chrysothamnus* sp.), and blue grama (*Bouteloua gracilis*), no individuals of the former shrubs exceeding perhaps three feet in height. After a short distance, as the hills are reached, the ascent becomes steeper and the road very tortuous. The foothills show many evidences of comparatively recent volcanic activity: there are many isolated cones surrounded by gently sloping lava beds which end in abrupt cliffs. The first trees are seen here, pinyon (*Pinus edulis*) and cedar (*Juniperus scopulorum*), but they are few and scattered. In one place there was noticed a large clump of aspens, which, by some strange anomaly of distribution, are two zones lower than they should be! Straggling pines (*Pinus brachyptera*) soon make their appearance, and as the tops of the lower hills are reached, the pinyon entirely disappears, to be replaced by a thin growth of pine.

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[1] Published by permission of the Secretary of the Smithsonian Institution.

[illegible] 1915

As the railroad first detours into New Mexico it reaches the Toltec Gorge, one of the finest bits of scenery in the state, where the Rio de los Pinos has cut through the mountains a deep pass with precipitous sides, similar to the Brazos Canyon, but probably not so deep and certainly not so long. As the train winds along its summit there is an excellent view of its northward wall, covered with a magnificent growth of Colorado blue spruce. The trees are the finest the writer has ever seen, each of large size, perfectly symmetrical, and with sufficient space to show itself to best advantage. The less steep hillsides above the gorge support a moderately heavy growth of Douglas spruce, white fir, and aspen.

The railroad soon recrosses the Colorado boundary, and, gradually ascending, reaches Cumbres Pass, the highest point on the line, having an altitude of 10,100 feet. The country east of the pass is very beautiful, consisting of wide, rolling, grassy meadows, flanked by densely forested slopes. Brooks and small lakes or ponds abound in the valleys. One of the lakes near Cumbres is the southernmost station for *Nymphaea polysepala*.

Leaving Cumbres the train descends a very steep grade along the valley of the Chama River and soon reaches the town of Chama, which has an elevation of 7800 feet. Several high peaks rise to the northward, but unfortunately they lie in Colorado, and the writer has not visited them, being always interested primarily in New Mexican plants. He botanized for ten days about this station in 1911, securing a large number of species that are known from nowhere else in the State. The vegetation in the vicinity of Chama is similar to that of the Brazos Canyon. The wagon road to the latter place follows the Chama Valley for perhaps twelve miles, then turns eastward to the canyon. The valley is broad with gently sloping sides, and toward Tierra Amarilla, the county seat, it is irrigated and apparently very productive. Much of the land is seeded to timothy, a crop that is rarely grown in the Southwest. The valley lies mostly in the lower part of the Transition Zone. It has been overgrazed by sheep with the result that much of the grass and other natural vegetation is replaced by weeds, such as that omnipresent southwestern plant, *Ximenesia exauriculata*, which in spite of its abundance apparently has never received a common name. In many places the alluvial flats are carpeted with a dense brown mat of some Polygonum, probably *P. litorale*. This short valley is not to be taken as typical of grazing conditions in Rio Arriba County, for the low mountains in this part of New Mexico are probably the best stock ranges in the state.

The Rio Brazos is a tributary of the Chama River, flowing into it near Tierra Amarilla. From its mouth eastward for about nine miles it flows through an open valley between low hills, but farther up it traverses a high plateau, through which it has cut a sinuous canyon from two to three thousand feet deep, and often less than a hundred yards in width. The canyon is bounded by perpendicular granitic cliffs, and ends abruptly at the southern escarpment of the plateau. For nearly a mile on the north side of the stream this escarpment is as abrupt as the walls of the canyon, then it changes into steep forested hillsides. At its foot is a great talus slope, along whose base the Brazos runs. The opposite side of the valley is inclosed by steep slopes, which rise to a level plateau, this finally falling gradually toward the west to the Chama Valley. The Brazos itself is a typical Rocky Mountain stream, swift, clear, cold, dashing over polished boulders, deepening here and there into great green pools which are the favorite haunts of trout. As it comes out into the wider valley toward Tierra Amarilla, it slackens, of course, and becomes wider and shallow.

In the region about the Brazos Canyon two life zones are represented, the Canadian and Transition, and on the highest summits there are faint traces of the Hudsonian. The Canadian Zone embraces the plateaus and all the higher slopes of the mountains, the "box" or the canyon proper, and the northward lower sides of the mountains, extending in narrow strips well down into the Transition along the streams, while the Transition Zone covers all the lower slopes, except the more abrupt northward ones, and spreads, in a modified form, down to the Chama River. Near Tierra Amarilla the Upper Sonoran is said to appear, coming in from the south, but the writer did not visit that region. The two zones are well marked in most places, except along the rock slides and rarely on the slopes at middle elevations, where there is sometimes an intricate association of plants which makes it impossible to refer a certain area definitely to either zone. The Canadian and Transition zones are not as sharply separated in New Mexico as are the Transition and Upper Sonoran, or the Upper Sonoran and Lower Sonoran; but, on the other hand, they are much more clearly differentiated than the Canadian and Hudsonian. The two latter zones in New Mexico are distinguished only artificially, even on the highest peaks where there is a broad expanse ofthe Arctic-Alpine Zone.

## CANADIAN ZONE

The vegetation of this area consists of heavy forest, frequently interrupted by open grassy meadows. The trees are *Picea parryana*, *Abies concolor*, *Pseudotsuga mucronata*, *Pinus flexilis*, *Negundo interior*, and *Populus aurea*, the first three being most abundant. *Picea parryana* forms almost pure stands at the higher elevations and scattered trees extend far down along the small valleys. It is conspicuous inside the canyon, especially on the faces of the cliffs, where many individuals manage to secure a foothold in small pockets or crevices. The white fir and Douglas spruce grow on the lower slopes and are often mixed with yellow pine. *Pinus flexilis* occurs only occasionally, and at the higher levels. The box-elder is rare, along the banks of the streams. Aspen is the most abundant tree in number of individuals, occurring everywhere as an undergrowth where the shade is not too dense, and forming nearly pure stands over large areas where the timber has been destroyed.

Of the shrubs several are common: along the streams *Alnus tenuifolia*, *Sorbus scopulina*, *Amelanchier* sp., and *Dasiphora fruticosa* are most abundant; in the Picea forests on the plateau above the canyon one finds *Distegia involucrata* and *Sambucus microbotrys*, the latter with small clusters of bright red fruit; while among the aspens there is an abundance of *Rubus arizoni-*

*cus, Vaccinium oreophilum, Atragene pseudoalpina, Odostemon repens, Pachistima myrsinites, Lepargyrea canadensis*, and *Juniperus sibirica*. The last is frequent on the rock slides and extends well down into the Transition.

This zone is rich in herbaceous vegetation and many of the most interesting plants of the region occur here. In aspen groves and on slopes among the coniferous trees the following are characteristic: *Pteridium aquilinum pubescens, Pyrola picta, P. secunda*, and *P. chlorantha, Erigeron superbus, Pedicularis grayi, Oreochrysum parryi, Anthopogon barbellatus, Dasystephana parryi, Silene menziesii, Anticlea elegans, Artemisia franserioides, Peramium menziesii, Antennaria microphylla, Calochortus gunnisonii*, and *Thermopsis pinetorum*. In crevices of the cliffs inside the canyon and on the rock heaps at their base the following are common: *Senecio pagosanus* and *S. taraxacoides, Rhodiola polygama, Draba helleriana, Erigeron leiomeris, Oxyria digyna, Cerastium scopulorum, Scrophularia montana, Rubacer parviflorus, Heuchera rubescens, Ionoxalis violacea, Pseudocymopterus anisatus, Leptasea austromontana, Potentilla concinna, Primula angustifolia*, and *Cryptogramma acrostichoides*.

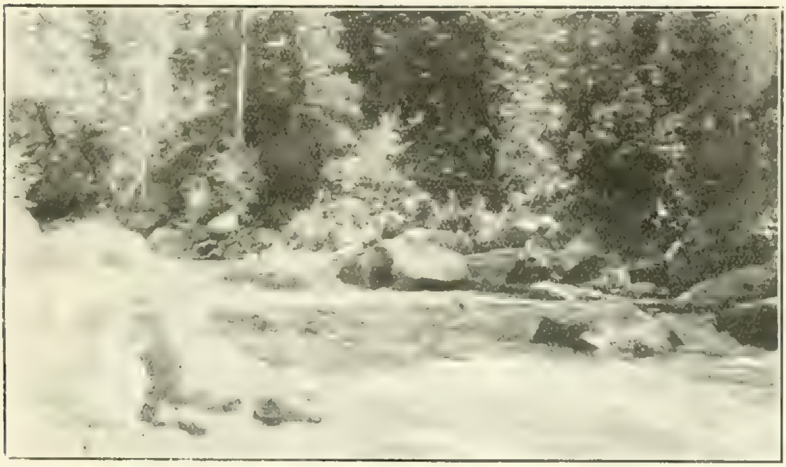

Fig. 1. Along the Brazos. The trees are Douglas spruce, with a few aspens.

On the summit of the plateau through which the canyon runs are many wide treeless expanses, thickly covered with grasses and other herbaceous vegetation. Here and there through the meadows are small ponds and sluggish streams bordered with sedges (*Carex* sp.). The ponds often contain *Sparganium angustifolium*, *Callitriche palustris*, and two species of Lemna. The meadow grasses are the tall-growing *Festuca thurberi*, *Poa interior*, *Danthonia intermedia*, *Stipa lettermanii*, *Sitanion californicum*, and *Phleum alpinum*. *Dugaldea hoopesii*, *Pyrrocoma crocea*, *Veratrum tenuipetalum*, and *Campanula petiolata* are abundant and showy plants.

It is along the small brooks tributary to the Brazos and having their source in springs at the foot of the escarpment of the plateau that herbaceous vegetation is rankest. Some of these streams fall down over rounded boulders; others have cut deep and narrow channels through the soil among the trees, often spreading out to form swamps. Characteristic of these hydrophilous plants are *Aster canbyi* and *A. burkei*, *Aralia bicrenata*, *Viola nephrophylla*, *Rumex occidentalis*, *Crunocallis chamissonis*, *Panicularia pauciflora*, *Calamagrostis canadensis*, *Actaea viridiflora*, *Aconitum bakeri*, *Rudbeckia laciniata*, *Capnoides brandegei*, *Senecio chloranthus*, *Epilobium novomexicanum*, *Ligusticum porteri*, *Conioselinum scopulorum*, *Alsine baicalensis*, *Sagina saginoides*, *Sanicula marilandica*, *Heracleum lanatum*, *Cirsium pallidum*, *Castilleja sulphurescens*, *Humulus lupulus neomexicana*, *Geum oregonense*, *Streptopus amplexifolius*, *Cynthia viridis*, *Hydrophyllum fendleri*, and *Mimulus pubescens*. The wild hop is very abundant on rocks along the brooks, and equally so is *Aralia bicrenata*, which gets to be four feet high or more. One of the most conspicuous plants is *Athyrium cyclosorum*, forming great clumps at the very edge of the water.

Mosses and lichens are abundant in this zone, as to number of individuals if not of species. The rocks along the streams are usually carpeted with mosses. Lichens are not frequent on the trees, although a species of Usnea is conspicuous locally, hanging from the branches of the spruces; but rock lichens are very abundant, covering the faces of the cliffs and the loose rocks of the talus slopes.

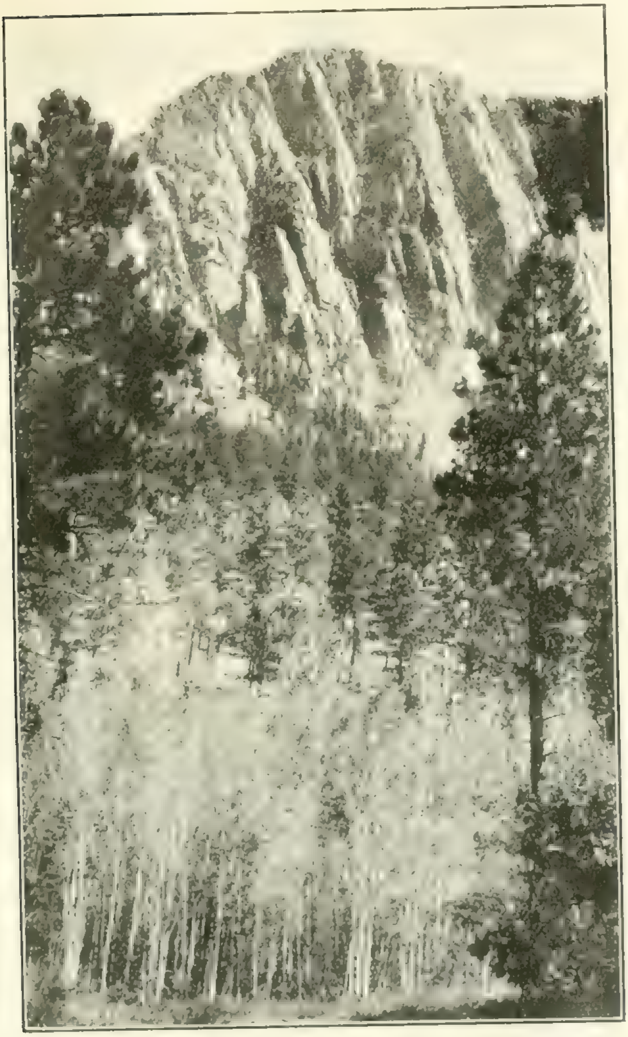

Fig. 2. Face of the escarpment of the plateau through which Brazos Canyon runs. Aspen in the foreground; yellow pine, Douglas spruce, and white fir in the distance.

## TRANSITION ZONE

Extensive lumbering operations have been carried on about Tierra Amarilla and well up toward the Brazos Canyon, whereever surface conditions are favorable. It is chiefly the timber of the Transition Zone that has been cut, for that of the Canadian Zone is usually on slopes or in canyons which are difficultly accessible. On the lower hills and in the valleys about Chama the general aspect of the vegetation has been much changed by man, and most of the large trees have been cut off. Apparently lumbering has been carried on in a rational fashion, and there are none of the burns or of the tracts covered with dead branches that spell desolation where the country has been "skinned," as it has in so many places in both the west and the east. The yellow pine is being gradually reestablished by nature and young trees are seen everywhere, while the white fir reproduces rapidly where conditions are at all favorable.

The vegetation of the Transition Zone in this region may be divided into two areas, typical Transition and Transition in which there is a large Upper Sonoran element. The first includes the mountain sides and the banks of the streams at their bases: and the second embraces the valley proper of the Chama River and the slopes of the low hills. The line between the two is rather sharply marked; for while both are, or have been, covered with yellow pine, the herbaceous vegetation is composed largely of different species, although many herbs and shrubs are common to both, just as many are common to the Transition and Upper Sonoran zones.

In the life zone map of New Mexico published recently[2] there is shown a broad belt of the Upper Sonoran extending along the Chama River from Tierra Amarilla to Chama. This is certainly incorrect, if one is to judge of the zones by the limits laid down by the author of the text which accompanies the map. The Transition, in northern New Mexico, is the zone of yellow pine, and all of the area under discussion is or was once covered by that tree, except along the banks of the streams. There is too great a tendency among makers of life zone maps to show the lower zones extending up into the upper ones along the streams. In New Mexico this is true in a general way of the large streams. In the great valley of the Rio Grande, for instance, taking the valley as a whole and not merely the flood plain of the river, the Lower Sonoran vegetation extends far to the northward. Along small streams, like the Chama and Brazos, just the reverse is true in a region of low rainfall like New Mexico. Here, under the favorable conditions of moisture, as well as temperature (although this latter is not readily apparent but is easily accounted for), the vegetation of the higher zones is carried far down into the lower ones and should be shown on a map as tongues extending down, not as recessions. This is probably not true in a humid region, but it certainly is the case in New Mexico.

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[2] Bailey, Vernon, Life zones and crop zones of New Mexico. N. Amer. Fauna No. 35. 1913.

### *Typical Transition Zone*

The one tree here is the yellow pine (*Pinus brachyptera*), except along the creeks, where the mountain cottonwood (*Populus angustifolia*) replaces it. The stand of pine about the Brazos Canyon and Tierra Amarilla is nowhere heavy, but this is doubtless the result of lumbering, for, farther west, on the Jicarilla Apache Reservation, under similar conditions, the stand is equal to any in the State.

The vegetation of this division of the Transition Zone is very uniform, except along the streams and on the rock slides, because the conditions of moisture, soil, and exposure are everywhere similar. On the rock slides few trees can find a foothold, but there are many shrubs, chiefly *Amelanchier* sp., *Padus melanocarpa*, *Grossularia leptantha*, and *Sericotheca dumosa*. A few scattered shrubs of *Juniperus scopulorum* were seen on the rocks, probably introduced by birds. Some of the herbaceous plants noticed as common are *Pericome caudata*, *Coleosanthus grandiflorus*, *Eupatorium fendleri*, *Chrysopis villosa*, and *Capnoides aureum*, these mingling with others that are properly Canadian. The banks of the Brazos are lined with mountain cottonwoods, which extend up as far as the mouth of the canyon.

Accompanying these trees are shrubs like the choke-cherry, service-berry, gooseberry (*Grossularia leptantha*), and willow (*Salix bebbiana*), and numerous hydrophilous herbs, such as *Aster laevis*, *A. frondeus*, and *A. wootonii*, *Apocynum scopulorum*, *Epilobium novomexicanum*, and *Prunella vulgaris*.

Elsewhere, on the slopes having normal conditions of soil, moisture, and exposure, there is usually a heavy shrubby undergrowth, composed chiefly of deciduous scrub-oaks. The thickets are often very dense, but there are many open places among them and at higher altitudes they gradually disappear. Other accompanying shrubs are *Padus melanocarpa*, *Amelanchier*, *Uva-ursi uva-ursi*, *Ceanothus fendleri*, *Symphoricarpos oreophilus*, *Odostomon repens*, *Berberis fendleri*, and *Sericotheca dumosa*. It was interesting to find *Yucca angustifolia* common in the Transition Zone, a few individuals growing in the shade even of firs. It had been believed hitherto that in New Mexico only one species of Yucca, *Y. baileyi*,[3] reached such a high altitude.

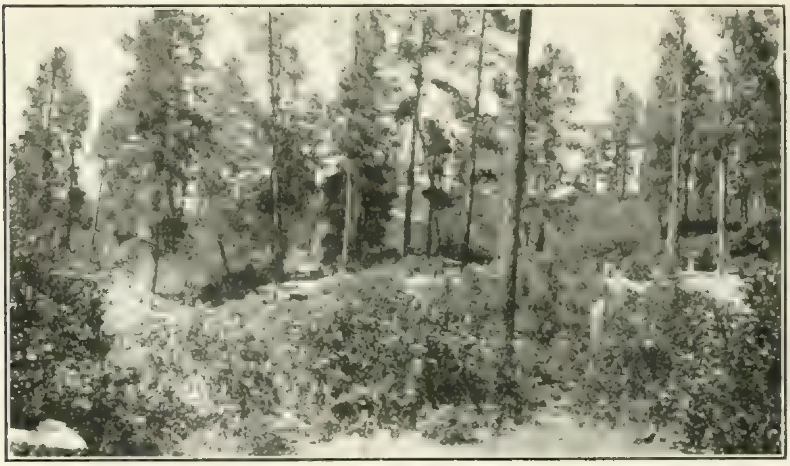

Fig. 3. Yellow pine with undergrowth of scrub-oak. Young pines may be seen on the right. This is typical Transition vegetation.

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[3] Contr. U. S. Nat. Herb. **16**: 114. 1913.

The herbaceous vegetation is varied, including numerous species, but the season was so far advanced that many of the earlier plants had withered. Prominent among those in flower or fruit in August and September were several species of Erigeron, *Machaeranthera bigelovii*, *Aster laevis* and *A. commutatus*, *Chrysopsis villosa*, *Orthocarpus luteus*, *Moldavica parviflora*, *Gymnolomia multiflora*, *Agoseris purpurea*, *Villanova dissecta*, *Achillea lanulosa*, *Gilia aggregata*, *Collomia linearis*, *Pentstemon torreyi*, *Gnaphalium strictum* and *G. sulphurescens*, *Andropogon furcatus*, *Vicia americana*, *Lathyrus leucanthus*, *Anisolotus wrightii*, *Rhinanthus crista-galli*, *Gayophytum intermedium*, *Polygonum douglasii*, *Lithospermum multiflorum*, *Castilleja confusa*, *Solidago trinervata*, *Arenaria confusa*, *Xanthoxalis stricta*, *Arabis hirsuta*, *Pterospora andromedea*, *Galium boreale*, *Thalictrum fendleri*, *Epilobium adenocladum*, *Lappula occidentalis*, *Oxytropis deflexus*, *Urtica gracilis*, *Anemone cylindrica*, *Geranium richardsonii* and *G. atropurpureum*, *Mentha penardi*, and *Silene hallii*. Despite the lateness of the season many plants of the wild strawberries, *Fragaria bracteata* and *F. ovalis*, were still in flower. The vegetation of this zone in the Brazos region, as a whole, is very similar to that of the corresponding tracts in the Santa Fe and Las Vegas Mountains, most of the species being common to both areas. The greater part of them, too, are found in the mountains farther south in the State, such as the Sandia, White, and Mogollon ranges.

## *Lower Division of the Transition Zone*

As stated before, in addition to many species typical of the Transition Zone, this area includes many plants common also in the Upper Sonoran. It is confined, in this region, to the valley of the Brazos, from Tierra Amarilla to within about four and a half miles of the mouth of the canyon, or the point where the river leaves the hills and comes out into a broad, open valley, to the lower slopes of the hills, and to the broad open valley of the Chama. The pines here have mostly been cut away, only the stumps remaining to show their original distribution. On the hillsides the scrub-oak gives place to sagebrush (*Artemisia tridentata*) and rabbit-brush (*Chrysothamnus graveolens*, *C. vaseyi*, and *C. parryi*), but these shrubs occur only sparsely and are nowhere so dense as one often finds them in typical Upper Sonoran areas. Some of the characteristic herbs are *Amaranthus powellii*, *A. pubescens*, and *A. blitoides*, *Pentstemon xylus*, *Chenopodium leptophyllum*, *Eriogonum cernuum* and *E. racemosum*, *Gutierrezia tenuis*, *Aster crassulus*, *Stanleya glauca*, *Helianthus annuus*, *Hymenoxys floribunda*, *Grindelia pinnatifida*, *Sideranthus gracilis*, *Bouteloua gracilis* and *B. prostrata*, *Agropyron smithii*, *Atriplex rosea*, *Boebera papposa*, *Madia glomerata*, *Anogra coronopifolia*, *Artemisia dracunculoides*, *Ratibida columnaris*, and *Senecio multicapitatus*. Nearly all of these are Upper Sonoran plants, but associated with them are fully as many others that are typical of the Transition Zone.

Where the valley of the Brazos widens there are broad flats, sometimes on one and sometimes on both sides of the stream. When the winter snows are melting the water cuts new channels across this flood plain, where it is not protected by cultivation, depositing soil in some places and in others washing it away and leaving beds of rounded stones or gravel. This area is overgrown with mountain cottonwoods, which reproduce rapidly and often reach a large size. Cedars (*Juniperus scopulorum*) grow with them in places, usually in thick shade, where they seem out of place. Probably cedars were more abundant formerly in the valley and on the hillsides, before they were cut for firewood. There are scattered shrubs of sagebrush and rabbit-brush here, as well as on the hills.

The herbaceous plants of the flood plain are much like those of the hillsides, except that there is a greater proportion of typical Transition plants. *Clematis ligusticifolia* climbs over many of the cottonwoods. Large areas are covered with a thick growth of *Antennaria microphylla* and a white-flowered perennial lupine. Many species of grasses abound, but the number of individuals is smaller than on the hillsides. On gravel banks and in moist soil common plants are *Argentina anserina*, *Halerpestes cymbalaria*, *Sideranthus gracilis*, *Aster* *wootonii*, *Verbena bracteosa*, *Munroa squarrosa*, *Castilleja linariaefolia*, *Madia glomerata*, *Marilaunidium angustifolium*, *Stachys scopulorum*, *Lactuca pulchella*, *Rumex mexicanus*, and *Lathyrus decaphyllus*.

The vegetation of the Brazos Canyon region thus illustrates two of the most characteristic life zones of New Mexico, the Canadian and Transition, the second of which shows two well differentiated subdivisions. It is typical of many of the mountain areas of New Mexico, although the writer is not prepared to state that the same divisions of the Transition can be made everywhere. Although scenically the region is equalled by few in the State, floristically it is surpassed in interest by many other areas, for in number of species the flora appears to be much inferior, for example, to that of the Santa Fe and Las Vegas ranges, and there is found none of that Mexican element which makes the White and Mogollon Mountains so interesting botanically.

# FURTHER OBSERVATIONS ON THE ORIGIN OF THE GALAPAGOS ISLANDS

ALBAN STEWART

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Probably the origin of insular faunas and floras will ever remain a fascinating problem for students of geographical distribution. I have read with much interest Scharff's excellent book, Distribution and Origin of Life in America,[1] and with especial interest that chapter that deals with the biological conditions on the Galapagos Islands. I wish to offer no criticism on this work as a whole, nor do I consider that I am in a position to do so, but I do feel that an entire year of residence upon these islands and my subsequent study of their flora, extending over a period of several years, enables me to speak with some confidence about the conditions which occur there, and to express an opinion concerning the origin of the flora, and of the islands themselves.

For one who is fairly well acquainted with the conditions upon these islands, I do not feel that Scharff has treated the subject with entire justice. Rather it seems that he has brought forward the evidence which best supports his own views in regard to the origin of these islands, etc., and has overlooked much other evidence that might well have been presented in a work of so extensive a nature.

It is hardly necessary to present in detail the different theories that have been advanced to explain the origin of these islands. It is sufficient to say that such authorities as Darwin, Wallace, Agassiz, etc. believed that they were oceanic, and that each island had arisen separately from the ocean. This theory was held for many years, and Baur[2] was the first one to oppose it seriously. His theory was, that the islands had all been joined together at some time in the past, and at a still earlier period they had been connected with the continent of North America, presumably in the region of Central America. Baur had not been upon the islands when he formulated his theory, but he visited them subsequently, apparently in part to obtain evidence to support his views. My own study of the flora of these islands[3] led me to a somewhat different view from either of the above—viz., that they are truly oceanic in their origin, but that they have been connected together at some time in the past in such a way as to form one or more larger islands, which by subsidence has resulted in the present condition. From the study of the flora I found no evidence which would lead me to believe that a land connection with either of the American continents had ever existed. In fact most of the evidence would lead to the opposite conclusion. As these views have been set forth in a former paper,[4] it is unnecessary to repeat them here.

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[1] The MacMillan Company, N. Y., 1912.

[2] On the Origin of the Galapagos Islands. Am. Nat. xxv, pp. 217–229, 307–326, 1891.

I do not wish to go into the zoological side of the question to any extent as there are others who are better qualified to criticise this part of the work than myself. I will, however, dwell briefly on a few important matters. It would have been rather appropriate for Scharff to have offered some explanation as to why there is a fairly abundant reptilian fauna upon the islands and at the same time an entire absence of batrachians. It would also have been well for him to have explained why the mammalian fauna, other than that which is known to have been introduced by man, consists only of bats, mice, and rats, for it is not likely that these would have been the only mammals that would have wandered there if the islands had ever been a part of the continent. It is hardly likely that the conditions could have been so adverse on the islands, since their supposed separation from the mainland, as to exterminate all but these few remaining forms.

The ability of the land tortoises to get to the islands seems to have been difficult for Scharff to explain, unless a former land connection with the continent be admitted. This has probably come about through an error that has crept into the literature concerning the ability of these tortoises to remain alive in water. Scharff quotes a statement from Gadow,[5] in which it is stated that land tortoises are drowned after a few hours' immersion in water, a statement that may be true enough for land tortoises in general but will not apply to the Galapagos Island tortoises as our own experience proved. While collecting at Iguana Cove, on the southwest side of Albemarle Island, it became necessary to load some tortoises into a small boat at some distance down the coast from where our vessel was anchored. The shore was unprotected at this place, and there was a strong swell running which broke heavily on the shore at times. The boat was capsized while loading one of the tortoises into it from the water, and before it could be gotten to a place of safety was caught by a heavy breaker and completely demolished on the rocks. The tortoises thus escaped in the water and it was thought that we had seen the last of them. We were very much surprised the following day, however, to find that the remains of the boat had been floated down in the vicinity of the vessel, and by keeping a sharp lookout we were able to pick up both of the lost tortoises during the day. They had been in the water twenty or more hours and did not seem to have suffered any particular damage, except that one of them had been slightly injured by being thrown against the rocks when the boat capsized. That they are able to live in the water for a much longer period is shown by the statement of Admiral David Porter[6] who spent some time in the vicinity of the Galapagos Islands during the early part of the last century. Porter mentions with regret the fact that the crews of some of the vessels, recently captured by him, had thrown their supply of tortoises overboard in preparing for action and states further: "*a few days afterwards*, at daylight in the morning, we were so fortunate as to find ourselves surrounded by about fifty of them, which were picked up and brought on board." He also says in this connection that these tortoises can be piled away in the hold of a ship for eighteen months without suffering any diminution in fatness or excellence. It can be seen from this that there is no reason for believing that these tortoises would not be able to remain afloat for weeks or even months without suffering greatly. They always float right-side-up in the water, and if they are inverted immediately right themselves as soon as they are released.

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[3] A Botanical Survey of the Galapagos Islands. Proc. Cal. Acad. Sci., fourth series, Vol. 1, pp. 7–288, 1911.

[4] *L. c.*, pp. 233–243.

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[5] Amphibia and Reptiles, p. 373.

[6] Journal of a Cruise made to the Pacific Ocean in the United States Frigate *Essex*, p. 162.

The suggestion of Dr. Stearns[7] that much animal life might have been transported on floating trees, etc., is criticised by Scharff, and the impression is given that the Humboldt is the only oceanic current that bathes the shores of these islands. This is probably true for the southern islands of the group, but not the northern, as they lie within the Panama current and the waters surrounding them are about ten degrees warmer than around the southern islands at the same season of the year, a fact that is also mentioned by Baur.[9] Pieces of bamboo and cocoanut husks are common constituents of the drift cast up on the shores of the Galapagos Islands. These could hardly be brought hence by the Humboldt current. Such a method of transport is thus possible, but whether or not mollusks, insects, etc., would be able to withstand so long a sea voyage I am unable to say. Presumably Dr. Stearns was sufficiently well acquainted with these to speak with confidence in regard to their tenacity of life.

The question is asked[10] why the agencies of accidental transport should have been so much more potent in the distant past than they are now. The vascular flora seems to answer this question by showing that these agencies might not have been more potent in the past, and that it is possible that many plants have been brought to the islands within comparatively recent times, or at least since the different islands became separated from each other. There are upon these islands some two hundred and sixteen species, varieties, and forms of plants, or 35%, of the flora, which are confined to a single island. Of these one hundred and one species are endemic, leaving one hundred and fifteen species, or about 18% of the flora with a wider distribution on the mainland. It is likely that further collecting upon the islands will extend the range of some of these species, but a large number of them must be confined to a single island, as many are of such a size that they would hardly be overlooked by even the most casual collector. *Sapindus Saponaria L.* is a conspicuous example of this class. There is such a similarity of climatic conditions at like elevations on many of the islands, as well as a similarity of soil, that it is improbable that so many species would be confined to such restricted areas if they had been present upon the islands before their final separation from each other. Furthermore, each succeeding expedition to the islands brings back a considerable number of species not before known to occur there, which have a wider distribution on the mainland. This might indicate that there is a more or less constant introduction of plants by the various agencies of chance distribution.

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[7] Mollusk-fauna of the Galapagos Islands, p. 366

[8] Stewart, *l.c.*, pp. 226-227.

[9] Baur., *l.c.*, p. 222.

[10] Scharff, *l.c.*, p. 301.

There are a number of erroneous ideas prevalent concerning the botanical conditions on these islands, among which is the supposed alpine flora. This idea has probably arisen through Wolfs'[11] observations on Charles Island. This author states that the vegetation at an elevation of 900 feet on this island bears a striking resemblance to the vegetation in the Andes mountains at an elevation of 9000 feet, a statement that was seized upon by Baur[12] to support his subsidence theory. If Wolf had made his observations at similar elevations on either the south side of Albemarle or Indefatigable Islands, or, at a somewhat higher elevation on James Island, he would have found the conditions entirely different from those he describes, and might have concluded that the general make-up of the vegetation was more like

[11] Die Galapagos Inseln, pp. 257-260.

[12] *L. c.*, p. 309.

that of the moist costal region of Ecuador than the mountainous part. On the three islands just-mentioned, there are lofty forests covered with lianes and epiphytes, while the ground beneath is carpeted with ferns and mesophytic plants, conditions which are about as far from alpine as could be well imagined. The peculiar conditions on Charles Island seem to be due to the loose nature of the soil and the smaller amount of precipitation. The same species, *Scalesia pedunculata*, forms a very large per cent of the forest trees on Charles, Indefatigable, and James Islands; they are low and rather stunted on the first of these, but lofty on the last two. The highest mountains on the islands must have been 14,700 feet high, according to Baur,[13] before the supposed land connection between the islands and the mainland was lost. Such mountains would evidently have supported quite an extensive alpine flora, some little of which should have persisted to the present time. I found but little evidence of anything of the kind in my collecting around the summits of the Galapagos mountains, the species which occur in such localities being usually of a more or less mesophytic type. They are in most instances, the same species which occur lower down, in the moist regions of the islands, but when they grow on the wind-swept areas around the summits, they are usually greatly reduced in size. There are no plants which have the rosette habit, large and brilliantly colored flowers, excessive pubescence, or other characters that one would expect to find in an alpine flora. If one confines his observations to the dryer islands, a desert flora will be found there but not an alpine flora.

The conditions around these mountain tops are such that alpine plants would probably have persisted if they had ever been present there. The vegetation is very low in many places so that it is hardly possible that alpine plants would have been exterminated by shading. Furthermore, the temperature around the summits of the mountains is far from tropical. I spent a night at the top of the mountain northeast of Tagus Cove, Albemarle Island, at an elevation of 4000 feet, and I passed the most of the time huddled over a small camp-fire shivering

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[13] *L. c.*, p. 309.

It was actually cold there, and this was in the month of March before the coolest part of the year had begun. Air temperatures below 70° F. are not at all uncommon at sea level.

The forms of *Euphorbia viminea*, which Scharff[14] discusses at some length, have little bearing on the subject of origin if we admit the possibility of a former union of the islands with each other but not with the mainland. If he had taken the trouble to examine the latest flora of these islands[15] he would have found that two of the forms described for this species have already been collected upon more than one of the islands. I believe that this will eventually have but little to do with the subject anyhow because there is some question about the distinctness of some of the so-called Galapagos Island forms. In fact I will shortly show that they do not exist in one of the species in which varietal forms have been described. We are dealing upon these islands with a variety of climatic conditions as well as different kinds of soil. It is often the case that a few hundred feet difference in elevation will show almost an entire change in the character of the vegetation, from extremely xerophytic to mesophytic types. A considerable number of species are not confined to any one of such zones, however, but may occur to a greater or less extent in all of them, with a corresponding change in habit and general appearance in each.[16] Some of the species which occur near sea level as mere bushes, assume the size of forest trees in the moister interior regions of the islands. Such marked changes in stature have a corresponding effect upon the length of internodes, size of the leaves, etc. Formal differences are of course very slight, and it is rather unsafe to establish them in woody species which may occur under a variety of conditions, unless we have a larger series of specimens upon which to base them than has thus far been collected from Galapagos Islands.

My own work on the flora of these islands is dismissed by

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[14] *L. c.*, pp. 314-315.

[15] Stewart, *l. c.*, p. 93.

[16] See Stewart, *l. c.*, p. 77 for changes brought about in the appearance of *Rhynchosia minima* (L.) DC. by the different climatic conditions at different elevations.

Scharff[17] with the statement that I have produced no new data for or against a former land connection with the mainland. It is true that I did not discuss this phase of the subject at great length in my former paper on the Galapagos flora, because, after I had tabulated my results[18] the evidence was so strongly against the theory of a continental origin that I considered an extended discussion superfluous. This table shows that of the eighty-one families of vascular plants represented upon the islands, only thirteen contain ten or more species. Of these Filices, and Compositae stand at the top of the list with seventy-seven and sixty-nine species respectively. Such a condition as this could hardly be possible if the islands were the remains of an extension of the continent, because many of these families are represented by a much larger number of genera on the mainland at the present time. We might well ask the adherents of a continental origin, why this condition should be, or why so many families are represented by but a single genus or even species. Surely the mere fact of isolation would not account for it because approximately 60% of the species of plants on the islands at the present time have a wider distribution on the mainland. Such a large per cent of non-endemic species would hardly remain if the conditions in the past had been very adverse. It seems that this condition can hardly be accounted for unless an oceanic origin of the islands is admitted. My work on the botany of Cocos Island[19] strongly bears out this view, as I have shown that the flora of this island differs greatly from that of the Galapagos. If we exclude those species which are known to have been introduced on both islands, there are but twenty-four common to the two, eleven of which are ferns. There are several more species of rather wide distribution common to the two, which might easily have been introduced with garden seeds, etc. In fact, Captain August Gissler, a resident of the Cocos Island for many years, told me that *Fleurya aestuans* Gaud. had appeared upon the island since he had been there, and that he thought it had been introduced from Panama. I found it only in the cultivated region around Wafer Bay. It would seem that Cocos Island should give us the key to the whole situation. Baur evidently considered this to be the most likely part of the ocean in which to construct his land bridge, as he states[20] that the 4000 m. line connecting the Galapagos with the central American coast, extends through Cocos Island. If such a land connection had ever existed it is very likely that there would be a much greater similarity in the floras of the two islands than is the case, as the climatic conditions are not so dissimilar but that eleven species of ferns are common to both.

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[17] *L. c.*, pp. 315-316.

[18] Stewart, *l. c.*, p. 235.

[19] Notes on the Botany of Cocos Island. Proc. Cal. Acad. Sci., fourth series, Vol. 1, pp. 375-404, 1912.

A relationship, though remote, between the floras of the Galapagos and Hawaiian Islands, is implied by Scharff.[21] We unfortunately have no very recent complete flora of the Hawaiian Islands, but from what is known I find that there are approximately twice as many of the Galapagos genera represented upon the Hawaiian Islands as there are Galapagos species. This is a relationship that is about as remote as it well could be, and if we exclude the single species of the Hawaiian genus Lipochaeta, which occurs on the Galapagos Islands, the relationship is practically nil. Hillebrand, in his work on the Hawaiian flora extending over a period of years, found no reason to believe that the Hawaiian Islands were ever less isolated than they are now. The water between these islands and the American continent is uniformally 3000 fathoms deep according to Hillebrand. To try to establish a land connection between these islands and the Galapagos, either directly or indirectly, seems to be preposterous so far as the botanical evidence shows.

My work on the Galapagos flora has led me to strongly believe that the only way we can account for its origin is through the chance methods of distribution of seeds and spores over large bodies of water. If we must invoke the aid of geographical changes to account for all the anomalous biological conditions that we find, truly the Pacific Ocean would look like a spiderweb if the ghosts of all the supposed land-bridges should suddenly rise up to confront us.

[20] Baur. *l. c.*, p. 221.

[21] *L. c.*, p. 317

# BOOKS AND CURRENT LITERATURE

**Limiting Factors and Plant Growth.**—A most interesting contribution to the subject of climatic conditions as related to plant growth, and one that has apparently escaped the notice of many students of this subject, is Smith's[1] study of the giant bamboo (*Dendrocalamus giganteus*), carried out in Ceylon. Lock's[2] previous studies in the same locality indicated that the growth of this plant is controlled by atmospheric humidity, while other workers had secured contradictory results, or ones indicating that temperature is the important controlling condition. In the study here considered Smith presents comparisons of the rates of growth of giant bamboo with both temperature and humidity conditions, and shows that the one or the other of these two conditions acted as the limiting factor, accordingly as one or the other was more variable during the particular time period in question. The very rapid growth rate of the plant here used, which exceeded two centimeters per hour in some instances, made it possible to compare the growth rates with the climatic conditions for relatively short time periods. The rapid growth is supported by a large reserve food supply and thus may not be compared directly with growth under conditions where there is no such supply.

The records of air temperature were obtained from shaded mercurial thermometers and those of relative humidity from readings of wet and dry bulb thermometers. Relative humidity does not, of course, fully express the moisture conditions of the environment as they may affect plant growth, but it may have been the most important factor influencing the moisture conditions in this case. The bamboos grew in moist soil along the borders of "tanks" or reservoirs, where the water supply was abundant. Large well-established clumps were selected for study at each of three stations, in different climatic zones: at Anuradhapura, in the hot, dry lowlands, 300 feet above sealevel; at Peradeniya, in the warm, moist region, 1500 feet above sealevel; and at Hakgala, in the cool, moist mountain region, 5600 feet above the sea. At each of these stations observations were made upon the growth of young culms at two-hour intervals during several days, and the growth rates were compared with the data of relative humidity and air temperature for corresponding periods.

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[1] Smith, A. M., On the application of the theory of limiting factors to measurements and observations of growth in Ceylon. Ann. Roy. Bot. Gard. Peradeniya **3**: 303–375. 1906.

[2] Lock, R. H., On the growth of the giant bamboos. Ann. Roy. Bot. Gard. Peradeniya **2** (Pt. II). 1904.

At Hakgala the humidity varied during the day, but was very close to the saturation point throughout the night. During the day the growth rates of the bamboo culms varied directly with changes in relative humidity, which ranged from 88 to 100 per cent, in spite of changes in temperature, which ranged from 10°–21°C. The rates of growth at night were usually much higher than the day rates. They gradually decreased from sunset until sunrise, thus varying directly with the rather small changes in temperature from 17° to 13°C. Temperature also seemed to be effective in producing very rapid growth during daylight periods of rain; since humidity was high at such times and the higher diurnal temperatures produced more rapid growth than occurred at night even with the same humidity. Thus, with nearly constant humidity, during cloudy days and at night, temperature changes appear to have been of primary importance in controlling growth.

Within the same temperature range, but with larger variations in humidity, the day rate was apparently mainly influenced by variations in humidity. Thus there were two limiting factors operating at Hakgala, temperature and humidity.

At the other two stations the relations of growth rates to temperature and humidity conditions were similar to those just described, but the response of the plant to temperature changes were here less marked than was the response to humidity alterations; changes in temperature were here comparatively slight (from 22° to 27°C.), but the humidity varied markedly and frequently.

The author emphasizes the point that relative humidity can be the limiting factor only in an indirect way, the real limiting condition being probably the transpiration rate, which is influenced by direct solar radiation, wind movement and the degree of stomatal closure, as well as by humidity. At all three stations the growth rates increased very markedly at sunset and decreased as promptly at sunrise, but the changes in humidity and temperature at these times were not considered to be rapid enough to account fully for these sudden alterations in growth. Smith attributes these alterations rather to the closure of the stomata at sunset and their reopening at sunrise and to the changes thus brought about in the rate of transpiration than to any direct influence of light upon growth.

Somewhat similar results were also obtained with a number of other plants.—F. T. McLEAN.

**Inorganic Plant Poisons and Stimulants.**—Under the editorship of T. B. Wood, professor of agriculture in the University of Cambridge, and of E. J. Russell, director of the Rothamsted Experimental Station, the series of Cambridge Monographs is making its appearance. Of these a thin volume of about one hundred pages by Miss Brenchley,[1] of the Rothamsted Station, presents the literature and our knowledge of the influence of copper, zinc, arsenic, boron, and magnanese compounds upon plants and the soils in which they are cultivated.

Pointing out that different concentrations of the same compound may act as stimulants to growth, or to other activities, or as repressants or poisons, Miss Brenchley briefly discusses the bases of the difference in behavior, without however leading to any definite conclusion upon the foundation of present knowledge. In regard to this and the other topics discussed, perhaps the most valuable contribution of the author is the evidence that, at present we know very little about the subject. At the same time it should be gratefully acknowledged that Miss Brenchley has saved the average plant physiologist much time and trouble by bringing together the major part of the literature and briefly discussing the principal contributions. Doubtless the specialist on plant poisons will miss the reference to certain papers, but to him such a book is less useful.

Two of the elements in this list of five are particularly interesting to Americans because of their general use in sprays, fungicides and insecticides, namely, copper and arsenic. The other three, zinc, boron, and manganese have a much more limited interest, although Miss Brenchley concludes that manganese may, under certain conditions, be a valuable stimulant to growth and crop production. Copper and arsenic appear not to act as true stimulants, the beneficial results of their use depending entirely upon the toxic action of dilute solutions of their compounds upon the parasites attacking their less readily permeable hosts. The effect of copper on germination, for instance, is nil or repressant; but the net result of its use may be advantageous, because the copper compound may have killed fungus and bacterial spores adherant to the seed coats.

This book confirms the impression, increasingly strong in the reviewer's mind, that the greatest need of the biological sciences today—of agriculture, horticulture, botany, zoology, and all their divisions—is the application to the study of living organisms of those qualities of mind, as well as the tools, which the chemist and physicist must possess or cease to be chemist and physicist in any proper sense, namely quantitative, not merely qualitative, accuracy. Biology has lagged behind, is still too largely a descriptive science, is still mistaking what is purely aviation for scientific hypothesis.—George J. Peirce.

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[1] Brenchley, Winifred E., Inorganic plant poisons and stimulants. Pp. 110, figs. 19. Cambridge University Press, 1914 ($1.25).

# NOTES AND COMMENT

A writer in the April issue of *Torreya* criticizes severely the manner in which papers are presented at the scientific meetings, giving a detailed diagnosis of the defects which he discovered in attendance at the Philadelphia session of the American Association. The titles are uninforming, technique and principles are intermixed, charts and diagrams are not allowed to speak for themselves, and the accompanying remarks are unduly prolix as well as tardy in arriving at the main point. Such is the verdict on what most of us have saved up as our supreme effort of the year! We may feel that the verdict is a little severe but we can at least recall other members of our section who have committed some or all of these defects. Our critic states that "contributors too often insisted upon laying before us their day-book instead of the ledger; indeed, the balance sheet itself would often be preferable." By all means! Let us have the balance sheet! There is no objection to having the most important items of the balance sheet in red ink.

It would be highly undesirable to make papers too brief and condensed, at least so long as our Sections and Societies refuse to print preliminary abstracts of the papers. It is a bad habit which causes many participants in scientific meetings to be highly detailed at the outset, while there is still plenty of time, and then to be so hurried after the secretary has whispered to them, that they are unable to present adequately the chief conclusions of their work. Whether we are listening to a paper or reading it in a journal the first thing that we want is a condensed statement of the problem attacked and the main results secured. It is a universal custom to summarize results at the close of a contribution. It is an equally universal custom to turn to the last pages of a published paper and read the summary before we begin to read the paper. It would be an extremely sensible proceeding to place the summary of conclusions at the beginning of a printed paper and to present the main conclusions of an oral paper during the first two minutes of its delivery.

Announcement has been made of plans for the celebration of the twentieth anniversary of the establishment of the New York Botanical Garden. The exercises will be held during the week of September 6, 1915, and will comprise addresses, the reading of scientific papers, opportunities for inspection of the grounds and collections, as well as a visit to the Brooklyn Botanic Garden, and two field excursions.

# THE DUNES OF LAKE MICHIGAN

THEO. J. STOMPS
*Amsterdam, Holland*

It was a great delight to me to be invited by Professor Cowles to join the International Phytogeographic Excursion in the United States during the months of August and September, 1913. In fact I feel inclined to acknowledge that the months I have spent in America, belong among the most happy ones which I have known in all my life. Friendship is the one thing we all need, whether scientific men or not. Friendship has fallen to our share from all sides during the excursion all along. A most hearty companionship always existed among the members of our party, leading to a better understanding of each other's work and to a higher appreciation of opinions which were not our own. And wherever we came, we were received in a most cordial way not only by fellow scientists but also by others who, though knowing little about our work, still showed a great interest in it; a continuous display of American hospitality. The excursion programme was arranged in a splendid way, allowing us to get an insight into the vegetation of a whole continent. One must get a feeling of perfect happiness by living, traveling, working for several weeks under such favorable circumstances. I wish to render thanks to my American friends for this most memorable summer and especially to Professor Cowles, our eminent leader. I can assure him, that I learned much in many respects, more than I ever could have expected.

I think we all got the impression, that our excursion was arranged in a progressive way. Gradually we passed to more interesting plant-formations and to more beautiful scenery. In order to fulfil my promise to Professor Cowles, to write a treatise on some point that has struck me most in the vegetation, I would therefore have to deal with my impressions of some trip or other made towards the end of our excursion. I shall not do this, however. Perhaps I can give proof of my indebtedness to Professor Cowles best by showing that the beginning of his excursion was already very interesting to me. Is it not a matter of course that one whose native country could not exist if it were not protected by dunes against the sea, felt especially attracted by the study we made of the dunes of Lake Michigan? Let me therefore say a few words about this region, which we visited immediately after our excursion had started in Chicago the first of August, and compare it with our Dutch dunes. Of course I cannot enter into particulars and must confine myself to the description of some general impressions.

The water of Lake Michigan is fresh and that of the North Sea is salt. This stands to reason, but is important to him who studies the flora of the adjacent territories, because it is connected with differences in the chemical characters of the soil. These differences are of two kinds. They bear upon the amount of common salt in the soil on the one hand and on the amount of lime on the other.

Of course the shore of Lake Michigan does not contain any salt at all. On our Dutch coast on the contrary salt in the soil plays a considerable rôle in the development of the flora, not so much in the dunes proper, but mainly on the middle and the upper beach. Middle beach I call, in agreement with Professor Cowles, that zone of the beach that lies between the high-water-marks of summer-storms and winter-storms and is colonized only by some annual herbs, because the possibility of survival through the winter period is excluded. The upper beach, not even flooded by the high storms in winter, presents the same species and in addition to these many others, especially perennial herbs with creeping rhizomes. As the middle beach is sometimes washed by sea-water and the saline water in the soil lies at a slight distance below the surface, as the air at the sea-side is usually very rich in salt-particles and during low-tide often large quantities of much salt-containing sand are blown landward from the lower beach, it is clear that our strand at least must bear a halophytic vegetation. It is generally known, that this is really so. All the annual species that grow on the middle beach, as for instance *Cakile maritima*, *Salsola kali*, *Atriplex littoralis* and *Atriplex laciniata*, are more or less succulent and belong to the halophytic type of growth. The same holds good for the species of the upper beach: here we find the same forms that occur on the middle beach and besides these many other halophytes, such as the succulent *Honkenya peploides* and *Convolvulus soldanella* and the glaucous wax-coated *Agropyrum junceum* all three inpossession of subterranean runners and the also succulent *Euphorbia Paralias*, a form that assimilates even in winter as do many plants in our dunes and multiplies by adventitious shoots from the roots. In short, we may say that the vegetation of our shore is distinctly halophytic. Even in our coastal dunes species with distinct halophytic characters are found, *e.g.*, the wax-covered *Eryngium maritimum* and *Glaucium lutum*, forms that dislike to grow away from the sea and seem to need, if not salt in the soil, then at least salt in the air. If we now compare with these conditions the situation on the shore of Lake Michigan, it must strike us at once, that there the aspect of the beach-flora is not halophytic. Such characteristic beach-plants as *Euphorbia polygonifolia*, *Artemisia caudata* and A. *canadensis*, *Cirsium Pitcheri*, *Xanthium canadense*, which we collected near Miller and Dune Park, Indiana, or *Strophostyles helvola* and *Petalostemum purpureum*, which we saw at Lake Bluff, Illinois, can not be said to have a halophytic appearance, nor can *Potentilla Anserina*, which Fuller mentions as characteristic of the beach in the list of dune-plants in his The vegetation of the Chicago Region, but which I cannot remember, to have found. So we have learned to know a first interesting point of difference between the dunes of Lake Michigan and those in Holland. This point becomes still more interesting, when we hear that after all some true halophytic species are to be found on the shore of the fresh water Lake of Michigan. The somewhat fleshy annual *Euphorbia polygonifolia* is properly speaking an example of this kind. I have found this same species near Wood's Hole, Massachusetts, on the beach of the Atlantic. Some other instances can easily be given. On the eastern shore of Lake Michigan the chief character-species of the middle beach, but thriving also on the upper beach or on windward slopes of active dunes, is the annual succulent *Cakile edentula*. This species also, a perfect imitation of our European *Cakile maritima*, I have collected near Wood's Hole, Massachusetts, and towards the end of our journey we have met with it again on the Pacific Shore at Carmel, California. Another halophyte, that we saw on the beach and in the dunes near Miller and Dune Park, Indiana, is the succulent annual *Corispermum hyssopifolium*, in Europe often locally a characteristic plant of the dune-flora of the coast. In Holland too it has been found, though in our country *Corispermum Marshallii* is more common, typical of abandoned potato fields in the dunes in the neighborhood of the sea. On the upper beach at Lake Bluff, Illinois, we studied among others a very interesting association of *Lathyrus maritimus*. This too is a marine species, occurring frequently on the Atlantic shore of America. It belongs also to the European coast-flora, having been found, *e.g.*, on the Dutch beach. Finally I could mention the Russian thistle, the variety *tenuifolia* of *Salsola Kali*, which I remember from our visit to Miller, Indiana. This example however is less important, because we are treating the feature of the beach-flora, but we did not find this species on the beach, but only in the dunes proper. Coming to a conclusion we may say, that, though the beach-flora of Lake Michigan on the whole is not so halophytic as it is in Holland, still some true halophytic types are present. It is not difficult to explain this fact, which at first sight might cause surprise. Life-conditions on the shore of Lake Michigan are extremely xerophytic, the summer sun being very hot and a strong wind loaded with sand blowing generally along the plants. We know that halophytes are merely a form of xerophytes, as much salt in the soil renders it physiologically very dry. It is therefore clear that the life-conditions on the non-saline shore of Lake Michigan are xerophytic to such a degree that they become almost equivalent to the halophytic conditions that exist, *e.g.*, in the neighborhood of Wood's Hole, Massachusetts, enabling in this way such plants as *Euphorbia polygonifolia*, *Cakile edentula*, *Corispermum hys-*

*sopifolium* and *Lathyrus maritimus* to grow on this shore. So we have seen that the study of the beach-flora of Lake Michigan is interesting from a double point of view. It is especially fit to make one feel, that halophytes and xerophytes are in reality similar adaptations.

I cannot close these notes on the beach-flora of Lake Michigan without calling attention to one very characteristic feature of the beach itself. I mean the line of driftwood, marking the upper limit of the middle beach, which is absolutely missing in my native country. It tells us on the one hand how rich the American country still is in primeval forests. We saw plenty of them ourselves. But on the other hand it shows how very prodigal Americans have been of their woods until now. So much wood has recklessly been cut in the forests on the moraine near Lake Michigan that large quantities of it could escape from the sawing-mills along the rivers and float to the lake without attention being paid to it. And one feels inclined to warn, to warn for the future, when all those forests will have disappeared, climates will change and no wood for human purposes will be available. Time has now come for a wise and economical management of American forests, as we have long known to be true for our European ones.

We now come to the second above mentioned point of difference between the dunes of Lake Michigan and those in Holland, that is connected with the freshwater character of Lake Michigan in contrast with that of the salt North Sea. We have already said that it is concerned with the quantity of lime in the soil.

As the water of Lake Michigan is fresh, it does not hide the enormous numbers of testaceans, that are usually present in salt water and of which we find the shells in heaps on the strand. Hence the diluvial sand, that builds the dunes of Lake Michigan, must be very poor in lime. The sand of our dunes on the contrary is, as a rule, very rich in lime and generally contains 3–4% of it. On the windward slopes of the fore-dunes the percentage can be much higher and rises to 12 or even 29%. Only in very old dunes, mostly situated far away from the sea, has the lime disappeared from the superficial layers of the soil. It has been dissolved by rainwater containing carbonic acid and by the influence of humus substances. In this way the soil of these old dunes has regained the properties of a normal diluvial soil, as it is found in those parts of Holland that are covered by heath. Only here such typical calciphobous heath-plants as *Pteridium aquilinum, Juniperus communis, Empetrum nigrum, Ilex aquifolium, Genista anglica* and *G. tinctoria, Calluna vulgaris* and *Erica tetralix* may be met with and they do not occur on the lime-containing sand of the younger dunes. If we now revert to our discussion of the dune-floras of Lake Michigan, we can not expect to find here something like the succession just described. In fact lime is missing everywhere in the soil of the dune-region and the visiting botanist can gather this immediately from the composition of the flora. Everywhere his eye discovers species that are known to be more or less calciphobous. An interesting example that we found growing at Miller, Indiana, quite near to the Lake, is *e.g.*, *Pteridium aquilinum.* This species is surely one of the most strictly calciphobous known and is nowhere to be found in our lime-holding dunes. Another example, also seen near Miller, Indiana, in the pine-dune-association, is *Juniperus communis.* This species passes for not so typically calciphobous as *Pteridium aquilinum* is. Still in our dunes it behaves as such and is strictly limited to the heath-covered parts, not being able to grow elsewhere. At Lake Bluff, Illinois, especially it showed to us with certainty, that even in young dunes no lime can be present in the soil. It was growing there almost on the beach, *e.g.*, near the entrance of the ravine, in which we saw *Thuja occidentalis* in abundance, and on the third row of the miniature dune area, which somewhat farther to the north, has drawn our attention. So this second example turns out to be still more instructive from our point of view than the preceding one. More instances can easily be cited, but I believe that my argument has been sufficient to show, that the freshwater character of Lake Michigan causes indeed a second fundamental point of difference between the dunes surrounding this Lake and those in Holland, the absence of a well pronounced succession, such as is found in the dunes of our country.

In passing, a short remark may be made on some peculiar representatives of the flora of Lake Bluff, Illinois. One of them I have named already, *Thuja occidentalis*. We were told, that this is a tree of relatively northern distribution, which on the east side of Lake Michigan only occurs in the northernmost parts. Yet it is included in the flora of Lake Bluff, which is situated near the southwest corner of the Lake. This case becomes still more interesting, when we hear that it does not stand alone and that the same holds true for several other species. The second and third row of small dunes on the beach at Lake Bluff were covered by *Populus balsamifera*, undoubtedly representing the cottonwood and conifer dunes of other places, actively moving dunes being absent here because of the feebleness of the easterly winds, that determine this dune-area. This too is a tree of relatively northern distribution, replacing at Lake Bluff the cottonwood, *Populus deltoides*, which we might, for instance, have expected from our studies of the dunes at Miller. Another example is *Juniperus Sabina procumbens*, one of the chief character-plants of the third row of the dune-area in question. Finally we could mention *Betula alba papyrifera*, large quantities of which grow on the forested cliffs near Lake Bluff. It is certainly interesting to note that so many northern species are found together here and it seems difficult to give an explanation.

Thus far we have mainly dealt with the influence of the fresh water character of Lake Michigan on the adjacent territories. The principal difference between the dunes in my country and those of Lake Michigan is however caused by another factor. I mean the value of the soil behind the dunes, which is much higher in Holland than it is in the Chicago region. In consequence thereof much more attention has been paid to our dunes by man and great care has been taken to prevent them from moving farther landward. As is generally known, this has been attained by planting them with tufts of *Ammophila arenaria*, one of the sand-reed-grasses, wherever it seemed necessary and natural vegetation was only sparingly present. The resultant impression is one of artificial rather than of natural vegetation in our dunes. In the dunes of Lake Michigan, however, nothing of the kind is seen and nature rules supreme. This especially makes the study of this dune region so extremely interesting. Nowhere can the formation of new dunes and the encroachment of the dune-complex on pre-existing plant-societies be better studied.

Seen from the beach our Dutch dunes offer a rather monotonous aspect. A low row of sandhills, almost equal in height and covered on their slopes and crests by tufts of the sea marram, extends all along the shore. Formation of embryonic dunes certainly takes place on the windward slopes of these shore-dunes, but in a very slight degree. As sand-accumulating species only some of the above named halophytic beach-plants can be mentioned, especially *Agropyrum junceum* and *Honkenya peploides* and besides these *Cakile maritima* and *Convolvulus soldanella*. The sand, that is blown landward is completely captured by the plantation of *Ammophila* on the foremost row of dunes. In binding the sand still other species are concerned, as *Elymus arenarius*, *Agropyrum pungens*, *Festuca rubra*, *Sonchus arvensis*, *Glaucium luteum*, *Eryngium maritimum*, *Cakile maritima*, *Salsola Kali*, *Convolvulus soldanella*, *Atriplex littoralis* and several other inhabitants of the Ammophiletum. Thus it will readily be understood that it is altogether out of the question that actively moving dunes could originate in my country. Not even do the fore-dunes grow considerably in height, because exceptional high storms take as much sand back to the sea as has been heaped up during a long period. Consequently, when one looks towards the interior from the top of a shore-dune, one sees an undulating country, here and there three miles broad, covered by vegetation all over. Some dunes are overgrown with thickets of *Hippophaë rhamnoides*, others with *Salix repens*, others again with a dense carpet of mosses and lichens, the most important of which is *Barbula ruraliformis*. Near the horizon the eye may discover a line of wood, the border of human plantations on the oldest dunes. Somewhat dreamy is the aspect of the whole region. It is hardly necessary to say that nowhere wandering dunes are seen to encroach upon human possessions on the inside.

How different from this is the situation on the shore of Lake Michigan. Here very many species help in building embryonic beach-dunes. In the first place the above named herbaceous plants of the beach, and besides these many others such as *Salix syrticola* and *glaucophylla*, *Prunus pumila*, *Calamovilfa longifolia*, *Ammophila arenaria*, *Elymus canadensis* and usually growing farther inland than the other types, *Populus deltoides* (cottonwood) or, northward, also at Lake Bluff, *Populus balsamifera*. It is clear that the difference in halophytic appearance between our coastal flora and that of Lake Michigan becomes still more striking, if we take the dune forming plants into the sphere of our considerations. Still it is worthy of notice, that here again there is a resemblance, in so far as many of the just-named species or at least narrowly allied forms also occur in our shore-dunes. This holds true especially for the sand-reed-grasses.

Equally richly varied as the formation of new embryonic dunes on the beach of Lake Michigan, is also the aspect of the dunes as seen from the Lake. Here high cottonwood-dunes arise immediately behind the beach and its embryonic dunes, and a complete study can be made of the dunes in the order of their development. There an extensive tract of bulky moving dunes, almost without any vegetation, presents itself to the eye. Yonder the shore has been largely eroded by lake-action, the cottonwood and pine-dunes have been swept away and oak-dunes border the beach. In short, the appearance of the shore-dunes as seen from the beach of Lake Michigan is far from monotonous.

In the same way the bird's eye view of the dune-region is much more interesting than it is in my country, especially where there are large areas of moving dunes with sparse vegetation, as is the case at Dune Park, Indiana, Michigan City and Sawyer, Michigan. I shall never forget the splendid view we had from the top of the "Crater," the well known 200-foot-high dune at Dune Park, lying in the midst of an extensive tract of wandering dunes. A mighty impression they make, those enormous volumes of rolling sand.

And that they are mighty can be seen, when they encroach upon swamps and forests, which they meet on their way, covering them up as they go. Nothing is then able to resist their power. We were lucky enough to see something of this encroachment on preexisting plant societies near Dune Park and Sawyer. About these observations, however, I will not enter into a lengthy discussion. Dr. Cowles has done this in an excellent way in his The Oecological Relations of the Vegetation on the Sand Dunes of Lake Michigan.[1] There is one point, however, which I should like to mention here. It is the behavior of certain swamp-plants, such as the willows and the red osier dogwood, *Cornus stolonifera*, when a moving dune is encroaching upon them. This behavior can very easily be understood by one who is acquainted with the habits of *Salix repens*, which is quite common in the dunes and swamps of Holland. He knows that *Salix repens* occurs in two types, the one on moist soil, standing erect, the other on slopes of dunes, crawling along the ground. So different are these two forms, that one might feel inclined to consider them as distinct elementary species. Still, that this assumption is unfounded is shown by the following observation. In order to prove this let us see what happens, when a moving dune has approached to the above named swamp-plants and begins to cover them. The erect habitus is lost and they begin to creep along the slope of the advancing dune, in the meantine shooting roots from their branches. This holds good of the willows as well as of *Cornus stolonifera*. Thus we see that these plants are able to leave their swampy localities and to adjust themselves to the dry conditions of the sandy slopes and this behavior is exceptionally important, because it enables the plants in question to partake in a powerful manner in the capture of an actively moving dune-complex by vegetation, in other words in preparing the dune-soil for the development of the pine-dune-association. But to the botanist this behavior is still more interesting from another point of view and I wish to conclude my paper with this remark. We have already treated of the similarity between xerophytic and halophytic adaptations. Now we have seen, that certain swamp-plants are able to thrive on a dune-soil, which is dry to such an extent, that even most of the xerophytic dune-species are not able to stand these conditions. No wonder then, that in many books on oecology the supposition is admitted that swamp-plants and xerophytic species also belong to the same class of adaptations.[2] *A priori* it does not seem difficult at all to argue this assumption. Swamp-soil, we read, is physically wet, of course, but physiologically speaking it is said to be very dry, mainly because of the large amount of humous acids present in it. On swampy soil the plants would therefore behave as if they were living in xerophytic life-conditions. In other words, it is expected *a priori*, that swamp-plants and xerophytes are similar adaptations and will be able to grow in each other's places. In Holland there are certainly plenty of species, that seem to prove the truth of this conclusion. *Salix repens* has already been named and other examples can easily be cited. There is *e.g.*, *Polygonum amphibium*, which usually grows in ditches and swamps, but often also on the driest places in the dunes. Inversely several of our heath-plants, *e.g.*, *Calluna vulgaris* and *Empetrum nigrum*, are to be met with in our peat-bogs. Very instructive in this regard are likewise the so called pine-bottoms, which we studied at Dune Park, Indiana. When a coniferous forest develops on established dunes, it usually happens on windward slopes and summits. But in certain low swampy depressions the pines may also appear and produce the pine-bottoms in question. Here the life-conditions are "oxylophytic," there they are certainly xerophytic and again we could get the conviction, that the two sorts of conditions are in reality identical. Still I am of the opinion, that we must be very careful in assuming the correctness of this hypothesis. Indeed I do not believe that swamp-soil may be called physiologically dry and I should say, that the explanation of the remarkable fact, that so many species are common to both xerophytic and swampy localities, must be looked for in quite another direction. In the first place I rather believe, that true swamp-plants, such as *Polygonum Amphibium*, that are able to thrive under xerophytic conditions, are extremely rare and only can do so by means of a double adaptation. Most of the plants in question *Salix repens* also for instance probably are typical of xerophytic life-conditions. These species are able to thrive on a swampy soil as well as in a botanical garden, if the struggle for existence with other swamp-plants be not too intensive. This is rarely the case, as a swampy soil is generally very poor in nutriment, which must exclude, of course, many species. If we further take into consideration that the xerophytic types in question are accustomed to bad life-conditions themselves, it can really not cause surprise that we meet them now and then in swampy places. In this way I believe that we must understand the phenomena just described, though I will not decide, of course, whether the swamp-plants growing on the dunes of Lake Michigan, are originally oxylophytic or xerophytic types. Coming to a conclusion I may perhaps say, that the main result of our visit to the dunes of Lake Michigan has been, that we got a better understanding of the value of the adaptations of halophytes, xerophytes and swamp plants.

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[1] Bot. Gaz. **27**, 1899.

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[2] See *e.g.* E. Warming, Oecology of Plants, Oxford, 1909, p. 193 a. f.

# NOTES ON THE DISSEMINATION OF VIRGINIA CREEPER SEEDS BY ENGLISH SPARROWS

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On February 19, 1914, while on a collecting trip in the outskirts of Colorado Springs, Colorado, my attention was attracted to a large number of bird excrements adhering to the rough bark of the trunk and limbs of a Cottonwood tree (*Populus deltoides*), which was growing in a sandy flood plain some fifty feet from a small stream. Closer examination of this tree revealed the fact that it had evidently been used, for some time, as a roosting place by the English sparrow (*Passer domesticus*).

Each excrement, then hard and dry, contained many seeds of the Virginia creeper (*Parthenocissus quinquefolia*). The excrements were plentiful and occurred from 10 25 feet above the ground. The Virginia creeper seeds in nature are covered with a berry-like pulp, which fact may explain why the seeds were eaten by birds. Moreover, for many weeks after the big storm of December, 2 5, 1913, in Colorado Springs, deep snow covered the ground, which fact may have compelled the sparrows to feed upon the berries in order to escape starvation.

At once the idea suggested itself to test the fertility of these seeds, and many were gathered. Also berries were collected from a living Virginia creeper vine some two hundred yards distant. The seeds of these berries were used as a check in the experiment.

### A. SEED FROM BIRD EXCREMENT

The twenty largest seeds were selected from ten excrements and planted one-quarter inch deep in a mixture of sandy quartz and loam soil. From four to eight seeds were found in each excrement. And, frequently the bird excrement completely enveloped the seed forming a hard covering over it.

### B. SEED FROM VIRGINIA CREEPER

The twenty largest seeds were chosen from the ten largest berries and planted one-fourth inch deep in a mixture of sandy quartz and loam soil. From three to six seeds occurred in each berry. It was a noticeable fact that the seeds from the bird excrements were larger on the average than those taken from the Virginia creeper berries. Of course, it is quite possible that the two classes of seeds did not come from the same vine. Again, it might have been due to the birds naturally choosing the largest berries for food.

The seeds from both vine and excrement were planted on February 20, 1914, and examined on March 24, 1914, thirty-three days later. The following table indicates the results obtained, being based on a planting of twenty seeds from each of the above mentioned sources.

*Table showing the percentage of germination*

| SOURCE OF SEED | [illegible] | CONDITION | HEIGHT IN INCHES | NUMBER OF PLANTS | PER CENT |
|---|---|---|---|---|---|
| From the Virginia creeper... | A | Good | 1$\frac{3}{4}$ and over | 7 | 35 |
| From the Virginia creeper... | B | Fair | 1–1$\frac{3}{4}$ | 5 | 25 |
| From the Virginia creeper... | C | Poor | 1 and under | 5 | 25 |
| | | | Total germination percent | | 85 |
| From bird excrement........ | A | Good | 1$\frac{3}{4}$ and over | 10 | 50 |
| From bird excrement........ | B | Fair | 1–1$\frac{3}{4}$ | 6 | 30 |
| From bird excrement........ | C | Poor | 1 and under | 3 | 15 |
| | | | Total germination percent | | 95 |

Referring to the foregoing table, it can be seen at a glance that the seeds taken from the bird excrement gave a higher percentage of good plants, a lower percentage of poor plants, and a higher total percentage of germination than did those seeds which came from a living plant. Again, the best developed plant from bird excrement seed measured 2$\frac{1}{8}$ inches in height, while the best developed plant from the Virginia Creeper berry seed attained a height of but two inches. However, the seeds from the Virginia Creeper berries appeared to germinate, on the average, a few days sooner than did those seeds taken from the bird excrement.

The seeds, in germinating, first sent down a tap root, and then raised their two seed leaves sidewise above the ground, while the stem formed an arch. Gradually this arch straightened until the seed leaves were borne erect, yet still enclosed within the seed coat, which finally split open and gradually wasted away until it dropped to the ground. Growth by the stem after that was more rapid. The seed leaves appeared to absorb the nutriment contained within the seed coat, for they were rather thick at first but soon became thinner and rapidly assumed a deeper shade of green.

On July 23, 1914, fifty square feet of space was marked off on the ground surface beneath the tree from which the bird excrements containing seeds were gathered on February 19, 1914. This space was clear, shaded, and of southeast exposure, surrounded by a heavy growth of grass. The soil was alluvial sand. On fifty square feet, seventy healthy Virginia Creeper seedlings were counted that had germinated under natural conditions. It seems reasonable to suppose that the most of these plants must have sprung from seeds that had passed through the digestive tract of English sparrows, as few excreta were found adhering to the trunk and limbs of the tree at this time.

From the foregoing observation, it would appear that seeds of the Virginia Creeper can pass through the digestive tract of the English sparrow and still retain their germinating power to a marked degree. This being true, it follows obviously that the English sparrow may, under certain circumstances, be an important agent in the dissemination of Virginia Creeper seeds in central Colorado.

# BOOKS AND CURRENT LITERATURE

Vegetation of Florida.—Two recent papers have treated the vegetation of portions of Florida with a greater degree of detail than any of the previous publications on this extremely interesting state. Harshberger[1] has described the region south of Indian River Inlet and Tampa, including the keys and the everglades, and Harper[2] has described the portion of the state north and west of Cedar Keys and St. Augustine, which is the least known portion of Florida from a botanical standpoint.

Harshberger treats the coastal vegetation and the less known plant life of the everglades and the interior swamp, marsh, and forest regions with equal detail. A large-scale map shows the precise distribution of the types of vegetation and a large number of uncommonly fine illustrations give proof of the distinctness of these types. The leading upland vegetations are the forests of *Pinus clausa* covering the sandy elevations along the coast and in the northeastern portion of the area; the forests of *Pinus caribaea* on oolitic limestone throughout the region; and the flatwoods of *Pinus palustris*. The region is depicted as one of climatic uniformity in which differences of soil and very slight differences of elevation are responsible for the dissimilarities of the vegetation. The porous soil and the rapid evaporation subject plants of the upland to extremely dry conditions, but the author has observed periods of heavy rainfall in which a saturated soil and a saturated atmosphere placed plants under conditions so unlike the customary ones as to lead him to suspect that the xerophily of the plants is due as much to the amplitude of the extremes of moisture as to the commoner conditions of low water supply. Topographic conditions are also responsible for the distribution of vegetation in the everglades, with their 4000 square miles of marshland dominated by *Cladium effusum*, their ponds, streams, and minor lakes, with a wealth of emersed and aquatic plants, their marginal prairies and pine forests, and the unique belt of *Anona glabra* which fringes the southern shore of Lake Okeechobee.

Harper's treatment of northern Florida is based on some twenty geographical subdivisions, corresponding closely to those used in his report on the peat deposits of the state. The topography, soils, leading economic features, and vegetation are separately described for each of these areas. A "quantitative" method devised by the author has been applied to the vegetation in such a manner as to give a rough approximation of the relative abundance of the leading species. Little attention has been given to habital differences in vegetation, but the contrasting features of the twenty areas with respect to the vegetation as a whole are very distinctly brought forth. Although the method of securing vegetational statistics is an indirect and somewhat arbitrary one the author confesses that he has sometimes adjusted them a little "if the results are obviously inconsistent with known facts." If there are some "known facts" in reserve why can't we have them? The author has, nevertheless, covered a very large extent of country with his rapid field method and has brought out some interesting results in correlating the vegetation with the geographical and agricultural features of this regions. Only six of the areas have less than 60 % of their vegetation composed of pines and other evergreens, and the general observation is made that the richest soils produce the smallest percentages of evergreens. A list of the 126 species of trees in northern Florida is appended, with a brief statement of the habitat of each. A large number of illustrations are collected at the close of the paper and a carefully elaborated index is given, designed to further the use of the bulletin by the non-technical reader.

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[1] Harshberger, John W., The Vegetation of South Florida. Trans. Wagner Free Inst. Sci. **7**:49–190. Pls. 10, with map. 1914.

[2] Harper, Roland M., Geography and Vegetation of Northern Florida. Ann. Rep. Fla. Geol. Surv. **6**:163–452. Figs. 41–90. 1914.

Both of the papers under notice give internal evidence of the zealous emphasis which their authors place upon the investigation of vegetation as contrasted with the study of the flora. In alluding to the fact that he made no collections in his field work Harper states that "those parts of the country where botanists are most particular about the correct identification of plants are generally those where the least progress has been made along phyto-geographical lines." If this geographical observation is indeed true for the United States it is because our oldest botanical institutions and our best stands of highly diversified or nearly virgin vegetation are separated by great distances. We must not forget, too, that most of our knowledge of the flora of the remoter portions of the country is due to the work of men located in the taxonomic centers. An impatience with regard to nomenclatorial exactness can be willingly brooked in a man who knows the flora of a region as well as our author knows that of the southeastern states, but it would seriously discount the phytogeographical work of a less experienced man.

Harshberger, in discussing the same matter, states that accuracy in specific determinations is highly to be desired, but continues "vegetation can be described without mentioning specifically a single plant." No one has yet done this but it is highly desirable to keep in mind the fact that in such work as Harshberger has done in Florida the names of the plants are a mere convenience, like the numbering of the buoys which mark a channel. It would be a notable event for some one to describe the vegetation of an extended region without using the names of any of the plants, for he would then be compelled to tell us a great deal more about the plants, and in fact would have to work much longer before being ready to publish. To the navigator who depends upon the numbering of the buoys the numbers are very important; to the navigator who takes his own soundings the numbers become superfluous. — Forrest Shreve.

The Transpiring Power of Leaves.—Physiologists and ecologists will be particularly interested in Bakke's[1] recent article on foliar transpiring power as indicated by tests with cobalt chloride paper. The method used was essentially Livingston's modification of Stahl's well-known cobalt chloride method of studying plant surfaces as to their ability to give off water. A determination is made of the time required for the change in color (from blue to pink) of slips of filter paper impregnated with cobalt chloride, when they are placed over a standard water-supplying surface of saturated blotting paper blanketed by a millimeter of air. The time required for the same change of the same slips is then determined when these are applied directly to the transpiring plant surface, by means of small glass clips. The ratio of the length of the first time to that of the second is the index of transpiring power of the plant surface in question; it is a number which expresses the relative ability of the plant surface to supply water to the atmosphere, and is directly comparable with other indices similarly obtained for different plants, or for the same plant at different times. It was the object of the investigation here reviewed to test the method upon a large number of plant species and upon different individuals of the same species. The work was done at Tucson, Arizona, upon plants growing mostly under irrigation.

A detailed study of the daily march of the foliar transpiring power of

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[1] Bakke, A. L., Studies on the transpiring power of plants as indicated by the method of standardized hygrometic paper. The Journal of Ecology, **2**:145–173. 1914.

*Quamoclidion multiflorum* gave results similar to those previously obtained by this method[2] and by the method of "relative transpiration."[3] The latter method, as will be remembered, consists essentially in determining the ratio of the rate at which a plant gives off water to the rate at which a standardized atomometer loses water by evaporation. To obtain a preliminary idea of the relative magnitudes of the diurnal and nocturnal indices of transpiring power, day and night observations were made upon a number of plant forms. There was found to be a broad range in the day-night ratio. The direction of the variation was found to be especially interesting: in the case of the more xerophyllous forms the ratio was generally less than unity; while it was usually greater than unity for the more mesophyllous forms.

Plants of *Verbascum thapsus* furnished opportunity for comparison of the relative transpiring powers of leaves upon the same stem but at different heights above the ground. The indices obtained for upper and lower surfaces, and the averages of these indices (representing the whole leaf surface) showed that the lower, older leaves exhibited lower transpiring powers than did the higher, younger ones. A necessary conclusion was that position upon the stem and age of leaves may be important in determining transpiring power, and also that an adequate idea of the foliar transpiring power of the plant as a whole can only be obtained by tests of a fairly large number of leaves. Tests upon transpiring power of floral parts showed that there was variation in this characteristic between different species, but that floral and foliar transpiring power were of about the same order of magnitude in plants of the same species.

Wilting has deservedly received much attention at the hands of investigators of the water-relations of plants, and studies here reported by Bakke upon wilting plants indicate that the method of standardized cobalt chloride paper should prove of great value in the study of this phenomenon. These studies showed that there is a marked fall in transpiring power as the plant wilts. Furthermore, they indicate that the time required for wilting in the case of plants surrounded by air having a high evaporating power is longer than that required with low evaporation rates, but that the amount of decrease in transpiring power is greater in the latter case. The author suggests that the need of irrigation might be predicted by this method of testing leaves, long before wilting is evident.

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[2] Livingston, B. E., The resistance offered by leaves to transpirational water loss. Plant World **16**:1–35. 1913.

[3] *Idem*, The relation of desert plants to soil moisture and to evaporation. Publication 50 of the Carnegie Institution, 1906.

Probably the most valuable point brought out in this article, and certainly the most interesting one to ecologists, relates to an ecological classification of plants based upon foliar transpiring power as shown by this method. The diurnal transpiring powers were determined for a large number of plants growing under irrigation. Plants which are unquestionable mesophytes exhibited indices of diurnal foliar transpiring power of 0.70 or higher, while all plants exhibiting similar indices of 0.30 or less would be pronounced xerophytic without hesitation, on the basis of simple observation. Although much more work must be done before a relative scale of xerophytism or of mesophytism can be erected, this preliminary study makes it certain that the method here employed offers a simply applied means for an ecological classification based upon quantitative measurements. Drought resistance in cultivated crops, in so far as water withholding capacity is concerned, can also be measured by this method, as Bakke shows by experiments upon two very different varieties of alfalfa and upon two forms of *Sorghum halepense*, Johnson grass, and Sudan grass. Further work in this direction should prove very interesting and valuable for economic purposes.

The paper here reviewed merits the attention of those engaged in studies in pure physiology, as well as of those investigating plants in the field, from either the agricultural or ecological point of view; the method seems to be very promising.—SAMUEL F. TRELEASE.

# NOTES AND COMMENT

A committee of representative investigators in heredity and variation have announced their intention to inaugurate a new journal entitled *Genetics*, provided a substantial body of support can be secured for it. The new periodical will be published bi-monthly, will contain about 600 pages per annum, and the subscription price will be $6 per volume. Dr. George H. Shull, of Princeton University, is the Managing Editor, and he has secured from the Princeton Press a promise of their willingness to manufacture the journal provided they can do so without too great an annual deficit. About seventy-five of the necessary two hundred and fifty subscriptions have already been pledged. The proposed size of the journal is exactly equal to the number of pages of American genetical work which Dr. Shull states were published last year in foreign journals.

At the San Francisco Meeting of the American Association there will be three symposiums on botanical subjects: on the Gymnosperms, on the influences of light upon plants, and on the geographic distribution of plants. The titles to be read in the last of these are as follows: Dr. John W. Harshberger, The Diversity of Ecologic Conditions and its Influence on the Richness of Floras; Prof. D. H. Campbell, Factors Affecting the Distribution of the Components of the Flora of California; Dr. Forrest Shreve, The Rôle of Physical Factors in Determining the Distribution of Plants; Prof. F. E. Clements, Plant Evidences of Climatic Cycles; Succession in the Bad Lands; Dr. W. A. Cannon, Distribution of Cacti with Reference to the Rôle played by Root-Response; Dr. W. S. Cooper, The Chaparral and its Habitat, and Plant Succession in the Palo Alto Region.

A third edition of Chamberlain's Methods in Plant Histology has been issued by the University of Chicago Press. The book presents all of the valuable features of the second edition, at the same time that it embodies the improvements in microtechnique made in the ten years that separate the two editions. A chapter on photomicrographs and lantern slides has been added. The detailed and trustworthy descriptions of the use of various reagents and imbedding and staining methods, as well as the specific descriptions of the best methods for use in the several plant groups, and the directions for the laboratory management of living material, make this an invaluable book for students and teachers of the morphology of plants.

Among the papers which will appear in early forthcoming issues of The Plant World are the following: A Study of the Root Systems of Prairie Plants of Southeastern Washington, by J. E. Weaver; Acid Accumulation and Destruction in Large Succulents, by E. R. Long; The Effect of Vanillin as a Soil Constituent, by J. J. Skinner; A Relative Score Method of Recording Comparisons of Plant Conditions and other Unmeasured Characters, by E. E. Free; and Notes on the Ancestry of the Beech, by Edward W. Berry.

The Rural Science Series, published by the Macmillan Company, now comprises some thirty-four hand-books and text-books, the most recent of them being the thoroughly revised twentieth edition of Professor Bailey's Principles of Fruit-Growing. The volume is not only concerned with the principles of the subject, but is even to a greater extent devoted to a complete exposition of the practices of fruit growing, from the selection of an orchard site to the packing of the ripened crop.

# A STUDY OF THE ROOT-SYSTEMS OF PRAIRIE PLANTS OF SOUTHEASTERN WASHINGTON

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## I.

While carrying on a study of the plant formations and associations of semi-arid southeastern Washington in 1912–1914, it soon became apparent that for a proper understanding of the development and structure of these associations a knowledge of the root-systems of the more important prairie species was imperative. Consequently, during the fall, winter, and spring of 1913–1914, more than 350 root-systems of 25 of the most important ecological species were examined. This paper contains descriptions of these, together with a discussion of the conditions under which the plants grow.

The prairies of southeastern Washington, and their eastward extension into adjacent Idaho, occupy a position between the foothills of the Bitterroot Mountains on the east, and the sagebrush region of western Adams, eastern Franklin, and western Walla Walla counties, Washington, on the west. On the south they are bounded by that high upfold of the lava-rock known as the Blue Mountains. Northward the Spokane gravels, extending somewhat southward of Spokane, with their open growth of yellow pine, mark at once the general northern boundary of the exposed part of the great lava sheet and its accompanying prairie formation. As the great Columbian Plateau with its wind-moulded hills ascends to an altitude of 2700 feet near its eastern border, the precipitation correspondingly increases, and this reflects itself in a more highly developed type of prairie vegetation. In fact, the well-developed high prairies occupy a relatively narrow belt of 30–50 miles in diameter along the eastern edge of the plateau, while the area westward is characterized by a very open type of Bunchgrass vegetation.[1] Pullman, Washington, the base station, where these studies were carried on, lies 85 miles south of Spokane and in the midst of the best developed type of prairie.

## THE FACTORS OF THE HABITAT

Since the supply of water in this region is the chief limiting factor to plant growth, we shall first consider the total amount of precipitation, with its seasonal distribution (which is of greater importance than the total), after which the water content of the soil will be considered.

Hemmed in on all sides by mountains, and especially cut off from the moist winds of the Pacific by the Cascades, the Columbian Plateau has a very low annual precipitation. In much of the area it is less than 10 inches, and even where the prevailing southwest wind, cutting through the mountain gap of the Columbia River and rising over the great High Plains, loses much of its moisture near the high eastern border, the annual precipitation is but 21 inches. In this semi-arid region where evaporation rates are very high, a knowledge of the distribution of rainfall and humidity is very important, for it is well known that scanty rainfall throughout the year, or relative dryness of the air and soil during the growing season, favors a sparse vegetation and the development of xerophytic forms. Since vegetation is not only an expression of present conditions, but to a greater extent a record of conditions that have obtained during a period of years; and since this record is not likely to be altered greatly by a year or two in which conditions may depart from the normal, a study of the precipitation in table 1 is instructive.

This table gives the mean monthly precipitation at Pullman covering a period of 22 years, and is very representative of conditions in the High Prairies.

It may be seen at a glance that over two-thirds of the precipitation occurs during the non-growing season, and that the light showers of July and August seldom have much influence on the water content of the soil. We may compare the soils of this region to a gigantic reservoir replenished mostly during the non-growing season, and (as will be shown) rather thoroughly emptied of its water during the summer. It is not the absolute rainfall figures alone which furnish a criterion of climate, for the maximum duration of the drought period constitutes a limiting factor of the greatest importance. The great problem is the extent to which soil water derived from the winter precipitation is conserved through the weeks of drought. The rains in southeastern Washington are so gentle that there is practically no run-off; and the silt-loam soils have a wonderfully retentive power of holding the moisture. As pointed out by Shreve[2] the influence of rainfall upon the distributional and seasonal activities of plants is obviously exerted chiefly through its power to replenish soil moisture, and while rainfall is only mediate in its relations to plants, soil moisture is immediate.

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[1] The writer has under preparation a paper dealing in detail with the vegetation of the prairies of southeastern Washington together with the plant associations of the adjoining mountain-woodland formation.

TABLE 1

*Precipitation at Pullman (in inches)*

| | | | |
|---|---|---|---|
| October | 1.70 | April | 1.50 |
| November | 3.41 | May | 1.84 |
| December | 2.66 | June | 1.20 |
| January | 2.55 | July | 0.57 |
| February | 2.18 | August | 0.68 |
| March | 2.02 | September | 1.29 |
| Total | 14.52 | Total | 7.08 |

## SOILS AND SOIL MOISTURE

The prairie soils of the region have originated from the decomposed underlying basalt. By the action of water, and especially by the prevailing southwest wind, the prairie topography has been moulded into rounded hills which reach a height of 100 to 360 feet, and resemble sand dunes. The soil is usually many feet deep, and only along the canyons of streams is the lava-rock exposed. The wind has drifted much surface soil and humus material from the exposed south and southwest slopes and deposited it upon the steeper north and northeast leeward slopes. Table 2 gives the mechanical composition of the first foot of soil on a northeast and southwest slope respectively.

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[2] Shreve, Forrest, Rainfall as a Determinant of Soil Moisture. Plant World, **17**: 9–26, 1914.

As is characteristic of dry regions, the transition from soil to subsoil is not well marked, although the lighter colored subsoil appears much nearer the surface on exposed than on sheltered slopes. The humus content of the soils of north hillsides is greater at all depths to 5 feet, in some cases more than 12% greater, than on the exposed slopes, as was shown by six sets of humus determinations made for each foot of soil on the two slopes, respectively. This combination of more clay and more humus on the north and northeast slopes reflects itself especially in the increased water-holding capacity of the soil. An average of six determinations gave a mean water-holding capacity of 56% (based on dry weight at 104 C. for the first foot of soil on north slopes, as compared with 48% on south slopes. This margin of 8% is rather an important difference in favor of the soils on the protected slopes, since the wilting coefficients of the two soils differ but little. These substratum differences are pointed out here since it will be shown later that certain plants are quite confined to moist north and northeast hillsides.

TABLE 2

*Mechanical composition of the first foot of prairie soils on a southwest and a northeast slope respectively*

| STATION | FINE GRAVEL 2.00 TO 1.00 MM. | COARSE SAND 1.00 TO 0.50 MM. | MEDIUM SAND 0.50 TO 0.25 MM. | FINE SAND 0.25 TO 0.10 MM. | VERY FINE SAND 0.10 TO 0.05 MM. | SILT 0.05 TO 0.005 MM. | CLAY 0.005 TO 0.000 MM. |
|---|---|---|---|---|---|---|---|
| Southwest slope.. | 0.00 | 0.60 | 0.60 | 0.40 | 23.58 | 73.30 | 1.49 |
| Northeast slope... | 0.40 | 0.40 | 0.90 | 1.50 | 33.16 | 53.50 | 10.03 |

Studies of the water content of these soils have been carried on since the spring of 1912. It will be unnecessary to burden the reader with all of the data and graphs obtained, and only enough will be given to make plain the seasonal march of soil water. In figure 1 are graphs giving the march of soil water from April 25 to September 25, 1913, on a typical northeast and southwest prairie slope, respectively. The ordinates represent percentages of soil moisture in the first 10 inches of soil, on the dates indicated by the abscissae. The rainfall between the intervals of readings is also shown in inches, each ordinate representing 0.1 inch. The horizontal solid and broken lines show the wilting coefficients of the soils on the northeast and southwest slopes respectively.[3] The greater amount of moisture on the northeast slope (in some cases being twice that of the southwest slope) may be noted at a glance; while the fact that the soil on the exposed slope reached its wilting coefficient about July 15, and more than five weeks before similar conditions obtained on the sheltered slope, is significant. Records for the fall of 1913 were discontinued when the rains of late September replenished the moisture of the parched soil. In 1914 these 10-inch soil moisture determinations were made only at longer intervals and with the object of determining the time at which the wilting coefficient was reached. The water contents on the dates of these determinations are indicated by the light lines (fig. 1), the solid line representing soil moisture on the northeast slope. The rainfall for June, 1914, being approximately normal (and not 1.6 inches in excess of the mean, as in 1913) the wilting coefficient of these soils was reached much earlier than in the preceding year. An examination of these determinations together with the rainfall records at Pullman, shows that at no time after June 28 and until September 14 was there water available for plant growth in the first 10 inches of soil on the southwest slope. Only 0.13 inch of rain fell in July, none in August, and the light showers of the first 13 days of September gave a total precipitation of only 0.33 inch.

The autumn and winter rains replenish the water lost during the long period of drought and in the following spring the soils again show a maximum water content. Soil moisture records obtained at 6 inches and 12 inches respectively, at the prairie stations on the two slopes from October 15, 1912, to January 1,

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[3] Samples of 100–150 grams of soil were invariably taken in duplicate, dried in an oven at 100–104°C., and the water content calculated in percentages on the basis of the dry weight.

1913, well illustrate this process. On October 15 the north-side soil had a water content of 17.4% and 23% at 6 inches and 12 inches respectively, while that on the south slope had only 11% and 12% at the two depths. The graphs show a general increase of water content (except for a trough in late November and on January 1 the water content had increased to 31% and 41% respectively, on the north slope, and 28% and 28% on the south slope.

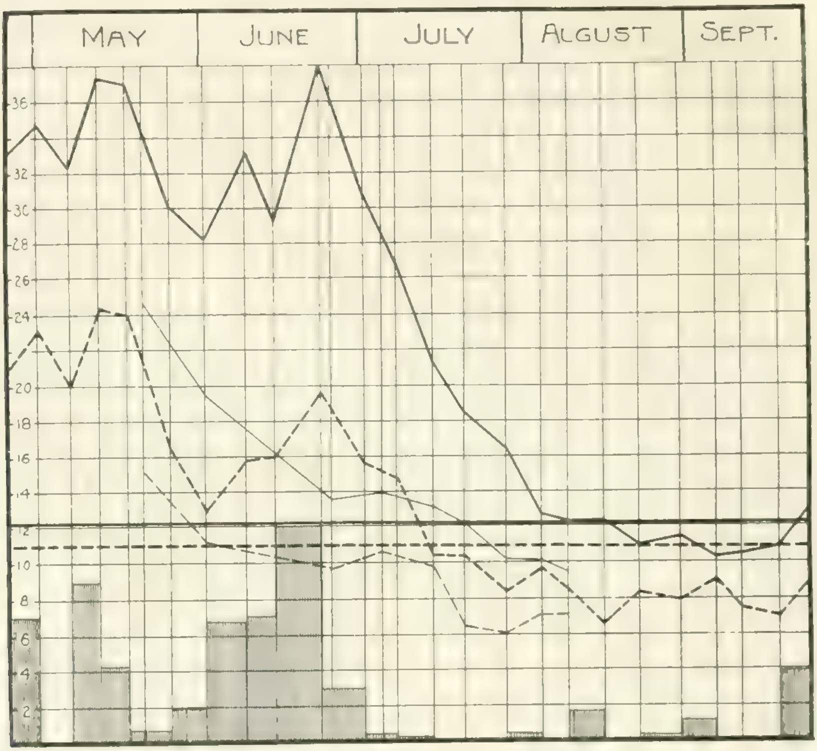

Fig. 1. Graphs showing the march of soil water to a depth of 10 inches from April 25 to September 25, 1913, (heavy lines), and from May 22 to August 10, 1914, on a northeast slope (solid lines), and a southwest slope, respectively.

It is apparent from these data that prairie plants must obtain their water from greater depths than 10 inches, at least during the dry summers. In fact, some of these plants penetrate to a depth of 12 or 13 feet, while most of them get the bulk of their water from the second to the sixth foot of soil. Consequently a consideration of soil moisture at these depths is imperative for a proper understanding of root environment. These deeper soil water determinations (many to a depth of 8 feet) were taken at intervals from December, 1912, to August, 1914. Samples were taken in duplicate from separate holes. Figure 2 (solid lines) shows the march of soil water from early spring until late summer of 1914, on a southwest slope. It is apparent that there was still a downward movement of water at depths of 4 and 5 feet after April 18; but from June 3 to August 15 the soil moisture was gradually depleted at all depths to 5 feet. The heavy horizontal bars give the wilting coefficients at the depths indi-

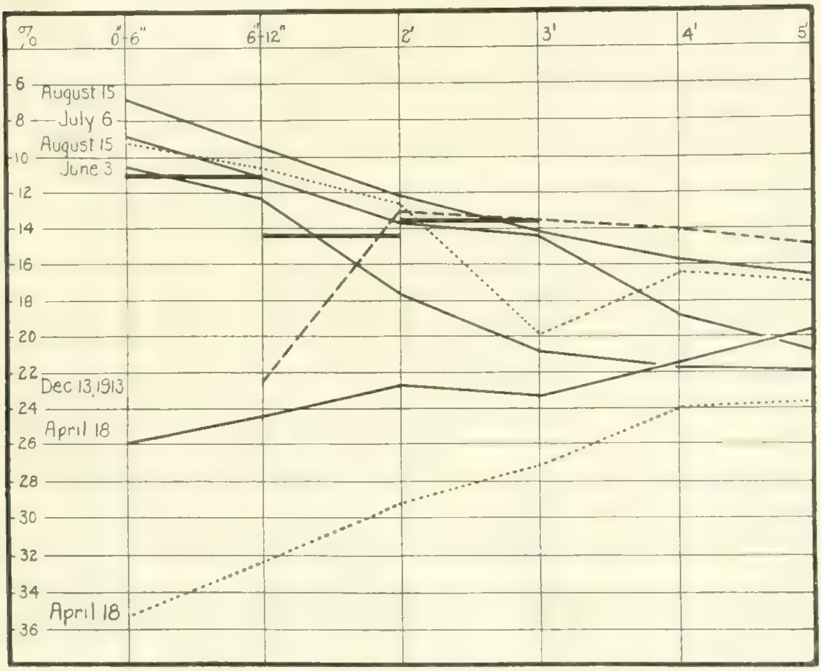

Fig. 2. Graphs showing the march of soil water to a depth of 5 feet on a southwest slope from April 18 to August 15, 1914; and the water content of the soil on December 13, 1913. The dotted lines indicate water contents on a northeast slope.

cated. On July 6 no water was available in the second foot of soil and only a small margin over the wilting coefficient was present at 3 feet. The broken line indicates that on December 13 of the preceding winter the soil was drier at 3, 4 and 5 feet respectively, than at any other time indicated. The fall rains had not then penetrated beyond 2 feet. While excavating root-systems during the fall, winter, and spring, an excellent opportunity was offered to study the rates of penetration. The water penetrated very slowly and at about equal rates on all slopes. By October 18 only the surface layer of 8 inches was wetted, and in late March the wet soil reached a depth of not more than 4 feet. The dotted graphs in the figure indicate the soil moisture on the northeast slope. Aside from the lower

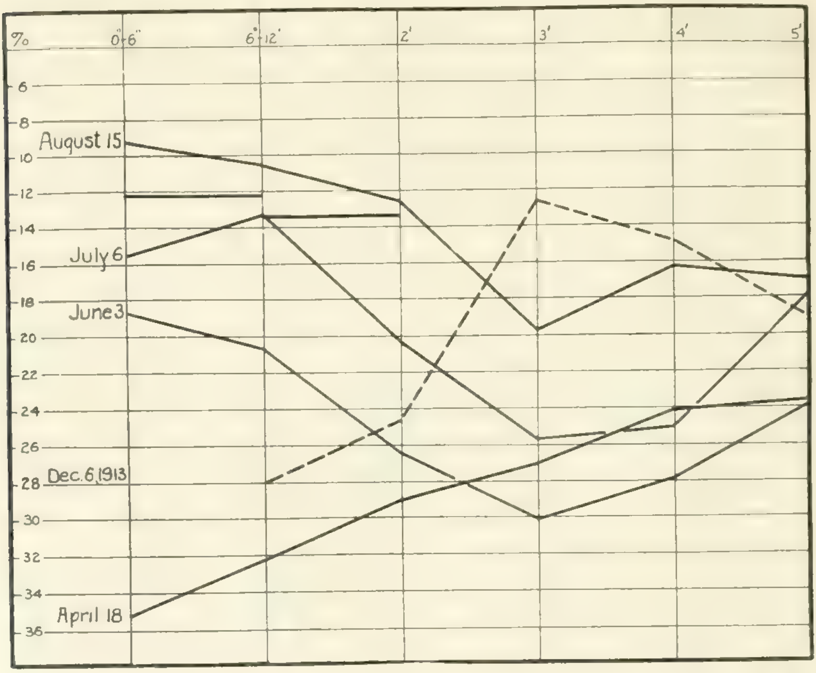

Fig. 3. Graphs showing the march of soil water to a depth of 5 feet on a northeast slope from April 18 to August 15, 1914, and the water content of the soil on December 6, 1913.

temperatures and greater humidity of the north slopes, the actual amount of moisture available to these soils is important in explaining the observed differences in moisture content. The same agency that has so profoundly affected the topography, namely the wind, also drifts over to the sheltered slopes much snow, which upon melting adds to the soil water. Two examples will suffice. In February 1914, exposed prairie slopes had a blanket of snow from 5–8 inches deep, while on the sheltered slopes at the same time drifts 48–52 inches in depth were measured. The second, while an extreme case, is illustrative. During February and March, 1913, while only 1 foot of snow lay on the south and southwest slopes, the protected northeast slopes were covered with drifts of well packed snow from 10–13 feet deep.

TABLE 3

*The march of soil water on a northwest and south slope respectively. 1914*

| | | MAY 22 | JULY 6 | AUGUST 15 |
|---|---|---|---|---|
| 0″–6″ | N.W. | 23.4 | 15.2 | 11.6 |
| | S. | 12.5 | 11.1 | 6.7 |
| 6″–12″ | N.W. | 25.7 | 13.7 | 12.1 |
| | S. | 17.9 | 11.4 | 10.2 |
| At 2′ | N.W. | 27.0 | 18.9 | 11.8 |
| | S. | 19.9 | 12.6 | 10.2 |
| At 3′ | N.W. | 30.2 | 23.7 | 14.4 |
| | S. | 20.2 | 13.2 | 10.6 |
| At 4′ | N.W. | 27.2 | 24.9 | 18.0 |
| | S. | 22.0 | 17.3 | 10.5 |
| At 5′ | N.W. | 24.3 | 21.3 | 19.5 |
| | S. | 22.4 | 19.6 | 12.3 |

In figure 3 is shown the march of soil water similar to that in the preceding figure, but for soils of a northeast slope. Here again, the downward movement of water at 3 to 5 feet after April 18 is apparent, as is also the gradual depletion of soil water at all depths to 5 feet. Likewise, the broken graph indicates conditions similar to those explained for the corresponding graph in figure 2. On August 15, no soil water was available above the 2-foot level. If the graphs in this figure are compared with the corresponding graphs in the preceding, it may be readily seen that in all cases, except on July 6 and at a depth of 5 feet, a higher water content was maintained in the soils on the northeast slope.

In order to further check these deep soil water conditions samples were again taken in duplicate on the northwest and south slopes of another prairie-covered hill. These findings, indicated in table 3, check very closely with the preceding, and the striking difference between soil water content on the two hillsides at all depths is well shown.

It may also be noted that at each determination the soil at any depth was much drier than at the same depth at the preceding determination. On the south slope, it is interesting to note that without exception the soil moisture increased with depth, and that the same condition maintains in most cases for north-side soils. Thus, it may be seen that topography with soil texture is the great middleman that distributes the soil moisture to fill the gigantic earthen reservoir, which again is largely emptied during the following growing season. The common farm practice in the Palouse region of alternating season after season the growing of wheat with summer fallow, is a method of storing the moisture from one year for use in the growth of the next year's crop.

## TEMPERATURE

The observations on the temperature of the soil consist of two series of readings, namely, of a continuous one by means of a thermograph and of a very large number of readings of thermometers. The thermograph records are at a depth of 4 inches (April 22 to June 9, 1913) and 3 inches (June 5 to August 15, 1914) respectively, on a southwest slope. Comparative temperatures on the northeast slope were taken at frequent intervals. The other thermometer readings are mostly for depths of 1 foot, and a number of readings were made at each foot to depths of 8 feet.

The thermograph records show an undulating line of which the curve crests correspond to the warmest period of each day, and the depressions to the coldest. The crests for any (7 day)

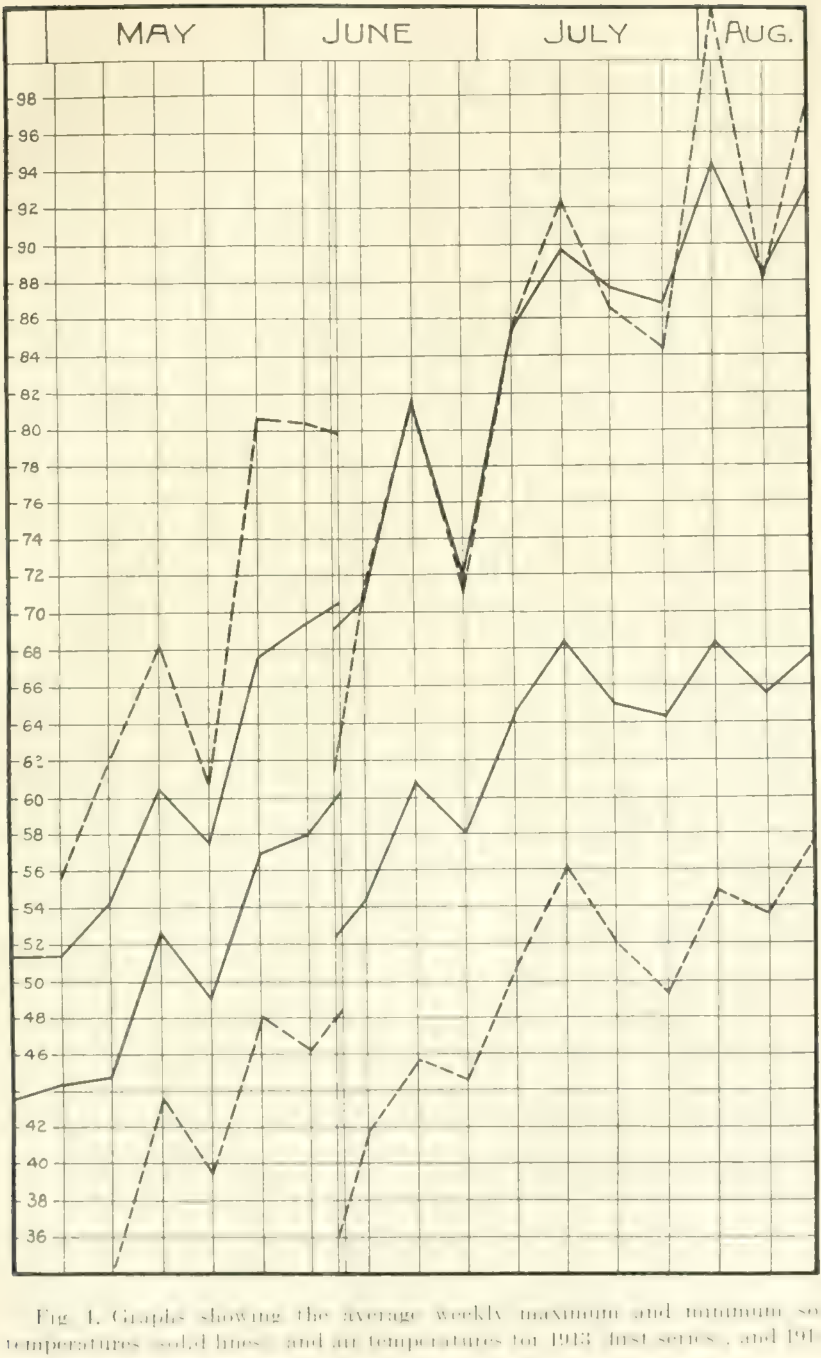

Fig. 4. Graphs showing the average weekly maximum and minimum soil temperatures (solid lines) and air temperatures for 1913 (first series), and 1914 on a southwest prairie slope.

record are remarkably uniform in height, as are also the depressions uniform in depth. The difference between the crests and the depressions is shown in figure 4 where the average weekly minimum and maximum soil temperature (solid lines) are recorded, since these are more important to plant growth than the mean. The differences between these averages increase from about 10 F. (at 4 inches depth) April to June, to about 24 F. (at 3 inches depth) in July and August. For purposes of comparison graphs representing the average weekly maximum and minimum air temperatures (at 3 inches above the soil surface and in the shade) recorded at the same station are also given in figure 4.

TABLE 4

*Soil temperatures at a depth of 3 inches*

| STATION | MINIMUM | TIME | MAXIMUM | TIME | RANGE | DAY |
|---|---|---|---|---|---|---|
| | | *a.m.* | | *p.m.* | | |
| N.E. slope | 63.5 | 5 | 75 | 3 | 11.5 | July 27 |
| S.W. slope | 67 | 7 | 93 | 4 | 26.0 | July 27 |
| N.E. slope | 59 | 5 | 71.5 | 3 | 11.5 | July 28 |
| S.W. slope | 68 | 7 | 94 | 4 | 26.0 | July 28 |
| N.E. slope | 61 | 5 | 73.5 | 3 | 12.5 | July 29 |
| S.W. slope | 67 | 7 | 95 | 4 | 26.0 | July 29 |

It is interesting to note that, while the soil temperatures at night were always warmer than those of the air, on many days during June, July, and August the air temperatures were lower than those of the soil.

Owing to the lagging of the soil temperature the maximum was not attained until about 4 p.m. and the minimum at 7 a.m. as compared with 3 p.m. and 5 a.m. respectively, for maximum and minimum air temperatures.

The seasonal march of soil and air temperatures varies inversely with the soil water. That is, the temperatures steadily become higher in proportion as the soils become drier. This condition occurred on both slopes, but the temperatures were lower and the extremes of variation less on the sheltered side. A single example of maximum and minimum soil temperatures on the two slopes and at 3 inches depth must suffice here.

The three days from July 27 to 29 were clear, and, judging from records of preceding and following days, quite typical. The daily maximum air temperature was reached somewhat earlier on the north than on the south slope, and was from 2°F. to 3°F. lower.

A comparison of a large number of temperature readings at 1 foot on the two slopes brings out the facts that at this depth the daily range of temperature is seldom over 1°F.; that the southwest-side soils are from 3°F. to 5°F. warmer in early spring than those of the north slopes, and that these differences may increase by late summer to 7°-10°F. Table 5 indicates these temperature differences of the soils of the two slopes to a depth of 5 feet, in early spring and in late summer. Undoubtedly the higher soil temperatures prevailing on the south side have much to do with the earlier seasonal activities of many plants.[4]

TABLE 5

*Soil temperatures at 1-5 feet on April 18 and August 15, 1914, on a northeast and southwest slope, respectively*

| | April 18 | | August 15 | |
|---|---|---|---|---|
| *Depth* | *N.E.* | *S.W.* | *N.E.* | *S.W.* |
| 1′ | 45.7 | 50.3 | 65.0 | 73.0 |
| 2′ | 45.1 | 50.0 | 61.7 | 70.0 |
| 3′.............. | 45.0 | 48.2 | 58.0 | 66.2 |
| 4′.............. | 45.0 | 47.0 | 57.2 | 64.4 |
| 5′ | 45.0 | 46.4 | 54.5 | 62.6 |

## OTHER FACTORS

Just as the possible growth of the aerial parts of plants is affected by the extent of the development of the root system, conversely the environmental conditions to which the aerial parts are subject, especially as concerns their water relations, must reflect themselves in the root development. Therefore, it will be instructive before passing on to a consideration of the root-systems themselves to consider briefly the above-ground environment.

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[4] Several species of plants were observed to blossom from 10 to 17 days later on north than on south slopes.

Enough will have been said about summer temperatures, if we add that the long days, mostly cloudless, are followed by cool nights, during which the temperature usually reaches 45–58 F. During the winter the ground seldom freezes below 4 inches in depth, and, of course, on the exposed slopes the process of alternate freezing and thawing is most pronounced.

A continuous record of humidity has been kept for more than two complete growing seasons and it has been found that the air is often 5 per cent to 10 per cent drier on the exposed than on the sheltered slopes. It is not uncommon on the dry slopes and during late afternoons for the humidity to fall to 15–30 per cent, while during the night it may rise again to about 75 per cent or even 95 per cent.

The wind, prevailingly from the southwest, is of great importance to vegetation, because it increases the evaporating power of the air, and the greater saturation deficit increases transpiration. During the season of 1913 (April 16 to September 3) a total of 13,605 miles of wind passed over the southwest slope at a height of 0.5 meter, while only 56 per cent as many miles were recorded by the anemometer similarly placed on a northeast slope. In general, these conditions were duplicated in the season of 1914 with the ratio of 100 : 49 (April 18 to August 15).

However, these factors of temperature, humidity, and wind movement, as Livingston has shown,[5] may be quite satisfactorily summed up by measuring the evaporating power of the air. A rather detailed report of evaporation rates as determined by Livingston's standardized porous cup atmometers in prairie and other stations has already been made,[6] in which it was shown that from May 5 to September 23, 1913, the average daily evaporation on the northeast prairie slopes was only 64 per cent of that on southwest exposures. Similar records for 1914 bear out this condition in general, with higher average daily evaporation on both slopes (23.9 cc. on northeast and 33.0 cc. on southwest) and a ratio on the two slopes of 72 : 100.

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[5] Livingston, B. E., Evaporation and Plant Habitats. Plant World **11**: 1–10. 1908.

[6] Weaver, John Ernst, Evaporation and Plant Succession in Southeastern Washington and Adjacent Idaho. Plant World **17**: 273–295. 1914.

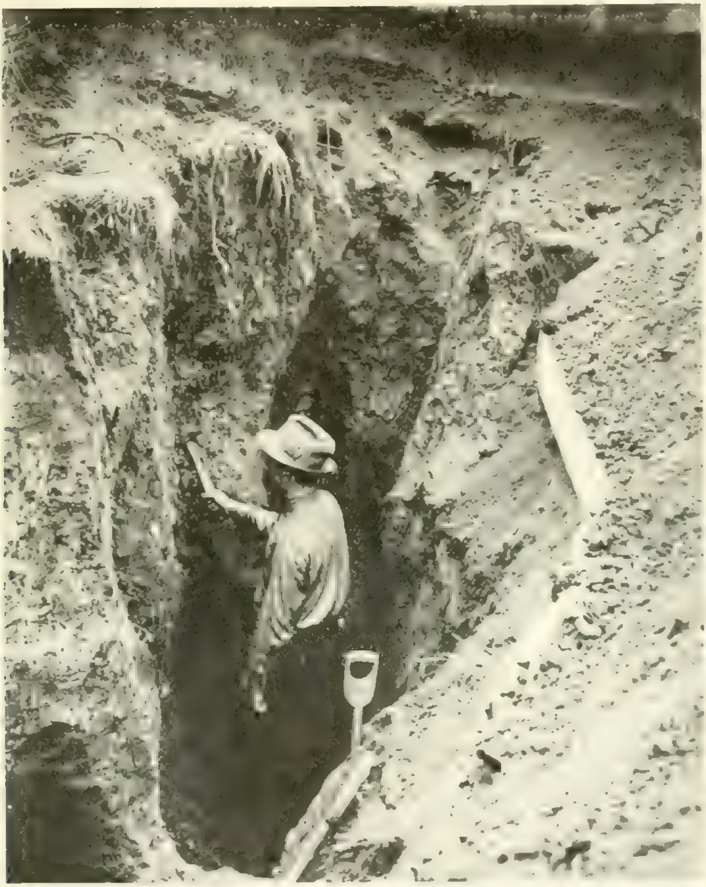

Fig. 5. One end of a trench used in excavating root systems. Many roots of prairie plants reach depths of over 10 feet.

When we consider that the daily evaporation in July and August often reaches a maximum of 40-55 cc., and at a time when the available soil water may be depleted to a depth of two feet, we can see the necessity for extensive root-systems in the substratum, as well as aerial structures for enduring drought. Another fact of importance must not be overlooked. Owing to the cool nights the greater bulk of these high water losses (82.5 per cent as determined for three days in July) occurs during the day, and thus very xerophytic atmospheric conditions are brought to bear upon the plant.

Summarizing briefly the factors of the habitat in which these studies were carried on, we find a region of moderate winter and low summer precipitation. The soils are composed of a fine silt-loom of high water-holding capacity, they are usually very deep, and the soil water extends down many feet beyond the greatest root depth.[7] In early summer the superficial layers of soil soon lose all of their water available for plant growth, and as the season advances this condition occurs in the deeper soils, while the entire soil mass to a depth of 5 feet and beyond, gradually yields up most of its available water. Soil temperatures at 3 inches show a daily range of from 3°F. to 24°F., while at 1 foot the daily range is seldom over 1°F. The seasonal range (April–August) of the soil temperatures varies from 22°F. at 1 foot to 16°F. at 5 feet. Air temperatures show a mean daily range varying from about 25°F. in April and May, to 38°F. in July and August. The cool nights on the high plateau tend to counteract the low humidity of the day and to reduce the high daily rates of evaporation.

North and northeast slopes are less xerophytic than the south and southwest slopes. This is due in part to actually greater precipitation caused by blowing snow and in part to soil texture which is more open, has more humus, and a greater water-holding capacity. These factors are reflected in the greater amount of soil water and in lower soil temperatures. Likewise, these slopes are sheltered from the drying southwest winds, and from the perpendicular rays of the sun. This is reflected in slightly lower air temperatures and greater humidity, and especially in the lower evaporating power of the air.

Wells dug only into the soil often afford a good supply of water, although usually they are drilled into the porous layers of basalt. See also Landes, Henry. Underground Waters of Washington. Water Supply and Irrigation Paper, No. 111, 1905.

## SCOPE AND METHODS OF THE STUDY OF ROOT-SYSTEMS

The object of this study was to determine the depth at which the most important prairie plants obtain their water supply; to get accurate data on the distribution and extent of the root-systems in the soil; and to examine enough plants of each species so that the conclusions might be thoroughly reliable. Finally, it was hoped to use these data in helping to solve the problems of succession and structure of prairie vegetation.

Owing to the tenacious structure of the soil and the great depth of most roots, it was found impracticable to wash out the root-systems. The method finally employed was to dig a trench 2 feet wide and 8 to 16 feet long to a depth of about 6 feet on the hillside where roots were to be examined. This offered an open face into which one might dig with a hand pick, and, after sufficient practice, and acquaintance with the soil texture, successfully excavate a root-system almost in its entirety. Of course the trenches were deepened as work progressed and the working level sometimes reached to a depth of 10 or 12 feet. See fig. 5. Five of these larger pits were used and several smaller ones.

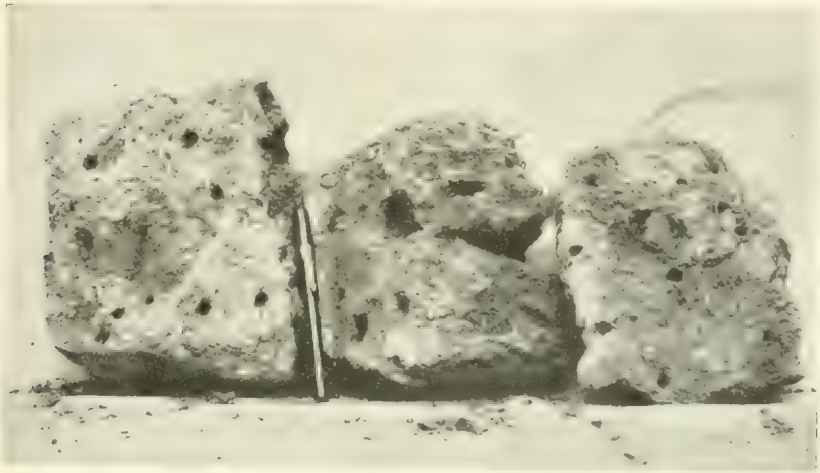

Fig. 6. Lumps of soil taken at a depth of 5 feet on a northwest slope, showing the numerous large earth worm burrows. They are from 7 to 8 mm. in diameter and reach depths of more than 13 feet.

The soils on the sheltered slopes were much more open in texture at all depths, and roots were removed with much greater facility than on south slopes where it was often necessary to use a pickaxe to open the trench.

Root-systems were examined on the southwest slope, and on a northeast slope, both, respectively, near the stations where factor determinations were made; and also on a northwest slope near the station where deep soil moisture samples were taken as a check (see table 3). It should be made plain here that this last station was on a slope only slightly north of west but sheltered by a low westward extension of a ridge in such a manner as to combine more nearly northside substratum conditions with the aerial conditions, as regards exposure to wind and sun, approaching those of a south slope.

A biotic factor affecting soil texture and one which shows a marked effect upon root-systems is the earthworm, a species of *Lumbricus*. The soils of north and northeast slopes especially, were literally honeycombed with holes ranging from 7 to 8 mm. in diameter and reaching depths of over 13 feet. (See fig. 6.) In the soil of south slopes the work of earthworms is much less in evidence, perhaps less than half as many holes occur here. Black soil was noted in these burrows at depths of 9 13 feet, perhaps in part worm-casts and in part surface soil washed down from above. Certainly these holes play a large part in the penetration of soil water, and it seems that the additional aeration they afford in these fine-textured soils might be of great importance.

All the roots examined were of mature perennial plants. The practice followed was to examine six or more roots of a given species and then to write a working description of the roots. These descriptions were kept at hand in the field and as new roots of the same species were studied any variation from the original description was carefully noted. It is believed in this way that thoroughly reliable results have been obtained for the species studied.

A few of the root-systems were photographed in place, but most of them were removed from the soil and afterward photographed, together with a meter stick, for purposes of comparing lengths. It was usually necessary to double the root one or more times in order to get it all on the ground glass at a distance close enough to show the details of structure. Root-systems of the following plants were studied.

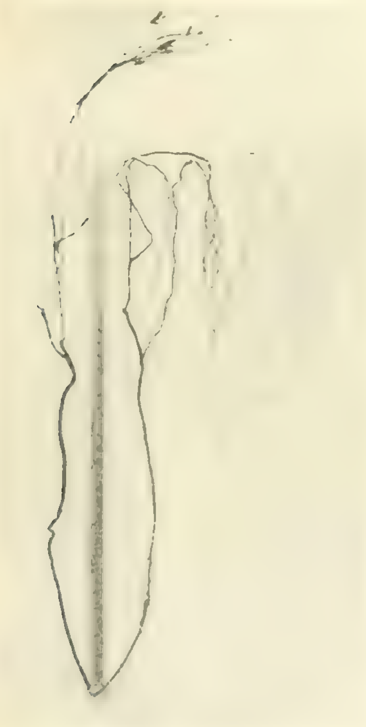

Fig. 7. A root of *Lupinus ornatus* with a length of 163 inches.

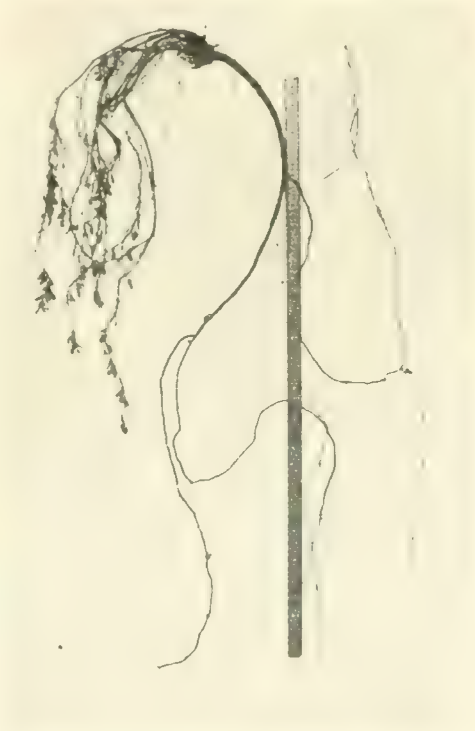

Fig. 8. *Lupinus leucophyllus* has a much larger transpiring surface and a smaller absorbing surface than the preceding species. Note the large root tubercles.

### *Lupinus ornatus* (*Fig. 7*)

Only two species of lupines occur widely distributed on the high prairies of eastern Washington. Of these *Lupinus ornatus* is the more xerophytic, while *Lupinus leucophyllus* rarely occurs except on moist north or northeast hillsides or in the narrow intervening valleys. The aerial parts of the lupines begin renewed growth in April, and come into bloom in June. *L. ornatus* remains green only until late July or early August, while *L. leucophyllus* seldom dries out until after the frosts of September. The dense coat of appressed hairs on the former, on both leaves and stems, gives the plant a silvery gray appearance, and as the aerial parts reach a height of more than a foot, they add considerably to the leaden aspect caused by *Balsamorhiza* and *Hieracium*. As regards abundance, an average of 7 plants per square meter is not unusual, while *L. leucophyllus* seldom averages more than one per square meter.

Twenty-four root-systems were examined. Several reached a depth of over 10 feet. The diameter of the tap root is seldom over 0.5 inch. It may have few or no large branches, but is often well supplied with wide-spreading laterals. The whole root is well clothed with fine rootlets to the third order, and the last foot or eighteen inches is often a mat of small branches and root hairs. In fact, the root hairs are far more abundant than on any other plant studied. The roots pursue a very devious course, especially in more compact soils. For example, one plant reached a depth of only 5 feet and 5 inches but the main root ran along under the ground at a depth of only 12 inches and for a distance of 4 feet. It sent up a whole thicket of stems. Another root, with a circumference of 1.5 inches, which it maintained for 3 feet, was over 10 feet long, but reached a depth of only 5 feet and 5 inches. When the top parts of the main roots die, sprouts, seen as deep as 3 feet, grow up to the surface. The average depth of the roots for all the plants studied was 7 feet and 7.1 inches. Nodules were found to depths of 11 feet. Nine plants on a northeast slope gave an average depth of 6 feet; five on a southwest slope, 5 feet and 11 inches; and ten on a northwest slope 9 feet and 10.4 inches.

### *Lupinus leucophyllus* (*Fig. 8*)

This lupine has a much larger transpiring surface and a much smaller absorbing surface than the preceding. Its tap root, which is seldom over 0.5 inch in diameter, may be abundantly branched all the way to the tip with short laterals (about 3 inches long), but more frequently it throws off several laterals at various depths. These vary in direction of growth from nearly horizontal to nearly vertically downward. All are profusely branched to the third or fourth order, especially near the tip.

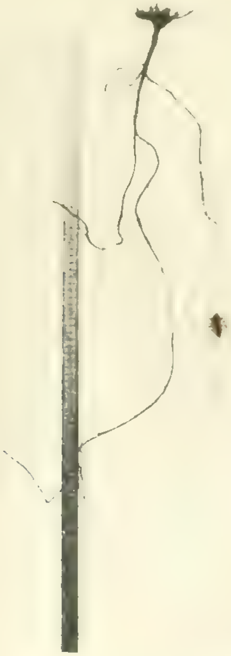

Fig. 9. *Astragalus (Phaca) arrectus.* This root reached a depth of 60 inches.

The nodules are much larger than those on *Lupinus ornatus*, often 10-15 mm. in diameter. As in the preceding plant, the legume taste is characteristic. Fourteen plants were excavated on a northeast slope. The deepest reached only 5 feet and 5 inches. The average root depth was 4 feet and 9.6 inches.

### *Astragalus (Phaca) arrectus (Fig. 9)*

Although a common prairie species, this plant is less abundant than *Lupinus ornatus*. Like most of its neighbors on the dry hillsides, it flowers early and dries up during the first week of July.

Six plants were examined on a southwest slope with an average root depth of 4 feet and 7.8 inches. The strongly developed tap root is seldom over 0.5 inch in diameter, usually pursues a course directly downward, and sends out many strong laterals at various depths. These laterals sometimes branch off even at 3 inches below the soil surface, and, like other laterals which may be thrown off all the way to the tip, often run in a rather horizontal direction before again turning downward. Like all the laterals, the tap root is usually profusely branched and the tip is also well provided with branchlets. One case was observed where the end of the tap root entered a worm hole at a depth of 47 inches and extended downward in the hole for 9 inches to its end, without branching, but it was densely covered with root hairs. *Astragalus* roots have a light tan color. The shortest root-system reached a depth of 3 feet and 4 inches; the longest, 5 feet and 10 inches.

(To be continued.)

# A RELATIVE SCORE METHOD OF RECORDING COMPARISONS OF PLANT CONDITION AND OTHER UNMEASURED CHARACTERS

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To all scientific investigators it is a common experience to find need of expressing more or less quantitatively relations which are not strictly commensurable or which for some reason or other are not measured. Students of plants, for instance, find frequent need of comparing the general health or "condition" of different plants and while this comparison is perhaps possible of reduction to precise terms through the actual measurement of turgor, color, speed and intensity of response to stimuli, intensity of metabolic functions, and the like, these units which go to make up the condition are so difficultly and laboriously measurable that such a procedure is usually impracticable. Ordinarily the judgment of a qualified observer, really formed of course from a more or less unconscious mental consideration of the various single features which go to make up condition, is a more accurate as well as less troublesome index of the existing differences. It has the further advantage of permitting decision immediately or almost immediately while actual measurement of the elements composing the condition would require a time so long as to give opportunity for important change during the progress of the measurement. It results that complex appearances such as plant condition are almost never measured in practice but are expressed merely as being better or worse according to the judgment of the experimenter.

The fault of this simple comparison is its lack of quantitative expression and this, while unimportant so long as only a few plants are under consideration, becomes very troublesome when many are to be considered or when non-simultaneous series are to be compared. For the partial escape of these difficulties two methods are in vogue. The first is the method of classification, by which the plants are placed in certain roughly defined classes, as for instance, "excellent," "good," "fair," "poor," etc. The second is the method of ranking, by which the plants are arranged in order of goodness, the best at the top of the list, the poorest at the bottom. An outgrowth of this second method is the assignment to each plant of a number (usually a percentage of "perfect" goodness) representing its relative position in the series. In certain cases, as, for instance, in scoring plants in agronomic judging, this number is made up of certain numerical units assigned to easily determinable elements of condition according to an arbitrary scale.

Both the method of classes and the method of ranking suffer from an important inherent difficulty, their dependence for accuracy upon the observer retaining constantly in mind the character and conditionof all plants of the series at the same time. With series of a few plants only this is not difficult but with scores or hundreds to compare it becomes practically impossible. Even the agronomic method of numerical scores for arbitrary unit features, suffers from this difficulty when the system of scores is first decided upon. It is practically useful, therefore, only when comparisons continue to be made on substantially the same basis and under substantially the same conditions. Because of the initial work necessary in the preparation of the score card the method is of no service in the numerous cases of comparisons on new or changing criteria which one is constantly called upon to make in the course of much biological research.

For nearly ten years the writer has been accustomed to meet this difficulty by a method derived from that used by the psychologists in the investigation of affections and which enables the formalization and partial quantitative expression of comparative judgments formed upon any criteria whatsoever. This method has proven so useful to the writer and associates in so many and so varied researches and seems so little known to investigators in experimental biology that it is here presented.

without, however, any implication that it involves principles essentially new.[1]

In essence the method consists in the individual recording, and later summation of each-to-each comparisons between each two individuals of the series being studied. It will be clearer by an example. The data are of an actual case of comparison between eight plants as to their general health and condition and are taken from an investigation now under way in this laboratory. The first step is to prepare a ruled sheet as shown in figure 1, the numbers of the last seven plants being set down in the upper margin, one to a column, and the numbers of the first seven in the left hand margin, one to a line. Plant number 1 is then compared with plant number 2 as to their relative condition—all other plants in the series being neglected. It is judged that plant number 1 is better. Accordingly in the space in the table corresponding to plant number 1 on the left and to plant number 2 on the top there is set down a "1" this constituting a "score" for plant number 1 and indicating that in that particular comparison plant number 1 was judged better. Proceeding, the comparison of plant number 1 with plant number 3 leads to a judgment that number 3 is better and a "3" is set down in the square to the right of the "1" first marked. Similar comparisons of plant number 1 with plants numbers 4, 5, 6, 7 and 8 indicate that in each case these are better than number 1 and the appropriate score is set down on the proper square. When plant number 1 has been compared with all the other plants in the series, plant number 2 is compared with each other plant (except number 1, this comparison having been made already), and the appropriate scores set down in the second line of the table shown. Plants numbers 3, 4, 5, 6 and 7 follow in turn with the results shown in the table. When plant number 6 is compared with plant number 7 no difference can be detected and an "a" is therefore set down, meaning that the plants are alike and counting as no score for either plant. It will be noted that the result, as shown in the table, is a record of individual comparisons of each plant with each other plant and of the judgment formed in each case.

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[1] A brief description has already been published by the writer, Jour. Physical Chem. **13**: 131 (1909).

To reduce this to roughly quantitative terms it is necessary only to add the scores given to each plant in the course of the comparison. Doing this, it is found that 1 has been scored once, 2 not at all, 3 three times, 4 twice, 5 six times, 6 and 7 each four times and 8 seven times. 8 is, therefore, in the best condition and 2, which was not scored at all, is in the worst. In figure 2 the results of adding the scores are plotted, the horizontal axis carrying simply the numbers of the plants and the height of the corresponding point above this axis being an approximate measure of the goodness of condition of that plant relative to the condition of the other plants in the series.

|  | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2 |  | 3 | 4 | 5 | 6 | 7 | 8 |
| 3 |  |  | 3 | 5 | 6 | 7 | 8 |
| 4 |  |  |  | 5 | 6 | 7 | 8 |
| 5 |  |  |  |  | 5 | 5 | 8 |
| 6 |  |  |  |  |  | a | 8 |
| 7 |  |  |  |  |  |  | 8 |

Fig. 1

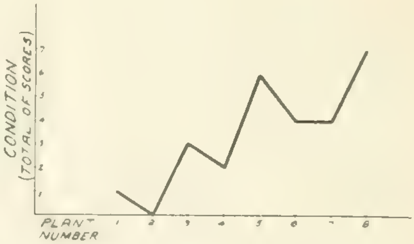
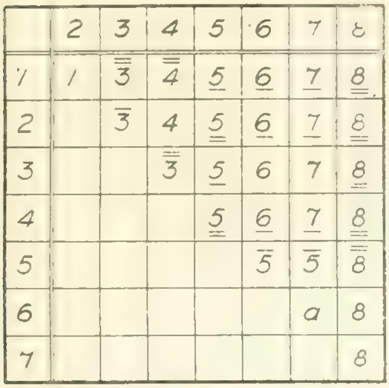


Fig. 2

It is apparent that the actual vertical difference between two plants next each other on the curve may not represent accurately the degree of difference in condition. Thus the curve of figure 1 would be the same if plant number 8 were only a little better than plant number 5 or if it were a great deal better. In some measure this can be corrected by a system of weighted scores indicated by overscoring or underscoring the figure of the score as set down in the table. The writer is accustomed to use five such weights as follows. The greatest difference existing between any two plants of the series is doubly under-scored thus "$\underline{\underline{3}}$." The degrees of difference less than this are divided into four divisions and marked in decreasing order by single underscore ($\underline{3}$), no weight mark (3), single overscore ($\overline{3}$) and double overscore ($\overline{\overline{3}}$). In computing the summation of scores the highest weight (double underscore) is counted as 5, the next as 4, and so on down to the double overscore indicating the slightest degree of difference which is counted as 1. Figure 3 gives the same comparisons as those of figure 1, but made on the weighted basis and table I gives the summation of the weighted scores. Figure 4 shows the weighted curve (the scale of ordinates being reduced to agree with that of figure 2) and it is seen that there is a large gap in condition between plants 1, 2, 3 and 4 and 5, 6, 7 and 8, which fact was not indicated by the unweighted method of recording the comparisons.



|  | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | $\overline{\overline{3}}$ | $\overline{\overline{4}}$ | $\underline{5}$ | $\underline{6}$ | $\underline{7}$ | $\underline{\underline{8}}$ |
| 2 |  | $\overline{3}$ | 4 | $\underline{\underline{5}}$ | $\underline{6}$ | $\underline{7}$ | $\underline{\underline{8}}$ |
| 3 |  |  | $\overline{\overline{3}}$ | $\underline{5}$ | 6 | 7 | $\underline{\underline{8}}$ |
| 4 |  |  |  | $\underline{\underline{5}}$ | $\underline{6}$ | $\underline{7}$ | $\underline{\underline{8}}$ |
| 5 |  |  |  |  | $\overline{5}$ | $\overline{5}$ | $\overline{\overline{8}}$ |
| 6 |  |  |  |  |  | a | 8 |
| 7 |  |  |  |  |  |  | 8 |

Fig. 3

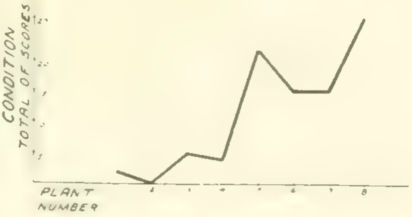


Fig. 4

The nature of the method and the manner of its employment will be apparent from this outline but one or two collateral matters deserve brief notice. First is the manner in which different sets of comparisons thus made can be reduced to comparable terms. Suppose sets of comparisons like those of figure 3 have been made on several separate series of plants. There is not necessarily any relation between the resulting curves since each applies to its one series only. However, if comparisons are then made on the same basis between the best plants of each series, or, for that matter, between any plants selected one from each series, the resulting curve gives the comparison between the different series and enables the reduction of all to the same basis, conveniently expressed on a scale of 100 for the plant in best condition among them all. Obviously a similar procedure permits the reduction of all comparisons to terms of any single standard which may be chosen, as, for instance, the condition of a control plant. In like wise it is possible to reduce the results of a series of comparisons to actual quantitative terms provided the criteria of judgment be such as to be measurable at all. Suppose, for instance, that plants have been compared as to their relative leafiness. If then the leafiness of any two of the plants be actually measured by counting the leaves per meter of stem or in any other way, the insertion of these measurements in the curve resulting from the original comparisons gives a scale by means of which it is possible to reduce the whole comparison curve to approximately quantitative terms. Procedures for the use of photographs for the comparison of series not synchronous or in proximity and for many other detailed modifications and extensions of the method will suggest themselves at once.

One caution is important, especially in connection with the method of weighted scores. In using this method on a large number of individuals in one investigation the writer employed it with nearly two hundred the mental criteria for the assignment of weights is very likely to change during the carrying out of the comparisons. Thus one will come at the end to give large weight to differences which at first were marked as small, or vice versa. This may be avoided very largely by making up the comparison table in irregular order. Thus, instead of comparing plant number 1 with all the others, then plant number 2, etc., as in the usual method, one takes first the comparisons of plant number 1 than, for instance, those of plant number 80 then those of plant number 36 and so on, skipping from one part of the table to another until all is finally complete. In this way any undetected changes of mental criteria during the course of the comparison will be distributed over the entire series and without important effect on the results.

It will be obvious that the method is not limited to comparisons of condition but can be applied to the expression of any comparisons whatever. By its use the writer and associates have made comparisons with reference to things so various as the color of chemical precipitates, the degree of flocculation of clay suspensions, the relative ruggedness of mountain ranges, the thickness of stand of native vegetation, the adhesiveness of wall paper to different plasters, and many others. Of course many of these things were actually measurable but the measurements were difficult, time consuming and unnecessary. For instance the degree of ruggedness of a mountain range might be measured in several ways by analysis of a contour map but to do so would require weeks or months of concentrated labor even granting that accurate maps were available. By the comparative score method the *relative* ruggedness of a dozen ranges can be determined in a few minutes by mere inspection of the maps or from a fairly good knowledge of the topography without any maps at all.

TABLE 1

*Summation of weighted scores*

| PLANT NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Score as counted | 2 | | 1 | 1 | 4 | 4 | 4 | 5 |
| | | | 3 | 3 | 5 | 4 | 4 | 5 |
| | | | 1 | | 4 | 3 | 3 | 5 |
| | | | | | 5 | 4 | 4 | 5 |
| | | | | | 2 | | | 1 |
| | | | | | 2 | | | 3 |
| | | | | | | | | 3 |
| Total... | 2 | 0 | 5 | 4 | 22 | 15 | 15 | 27 |

In conclusion it may be emphasized that this method is simply a system of facilitating, recording and formalizing judgment and is nothing else whatever. It depends for its accuracy entirely upon the correctness of the individual judgments the results of which it expresses. If these be wrong the scoring of them will not make them any less so. Like all mathematical or quasi-mathematical procedures absolutely nothing comes out of the process except what goes in. It is impossible to lay too much stress upon this limitation, for the apparently quantitative expressions derived by this method are likely to seem more valid than they are and to blind the user to their absolute dependence upon the individual judgments from which they are built up. From all of this it follows that the method is valuable only when correct judgment is possible which means, usually, criteria of difference which are definitely understood and appreciated, the possibility of simultaneous comparison, and a series the differences within which are not so wide as to confuse and hamper the individual judgments.

# BOOKS AND CURRENT LITERATURE

A Text-Book of Grasses.—A recent publication of note is A Text-Book of Grasses, by Prof. A. S. Hitchcock of the Department of Agriculture, Washington, D. C.[1] This is one of the Rural Science Series edited by L. H. Bailey, and is certain to prove valuable not only for the general readers but also for the student of grasses. It contains many illustrations which make it of special value to the layman who wants to know about the common grasses and forage plants.

The book is divided into two parts, Economic Agrostology with 88 pages divided into 10 chapters, and Systematic Agrostology with 167 pages and 15 chapters. Under Economic Agrostology such subjects as forage plants, cultivated pastures, meadow plants, lawns, grasses as weeds, grasses for miscellaneous purposes and grass crop areas are discussed. The treatment of most of these subjects is too brief to be of great value even to the ordinary reader. The subject of grazing ranges and range grasses is manifestly not as good as it should be. The real factor in building up grazed-out ranges in the west is to insure seed production by means of alternate grazing and resting of the areas concerned. This part of the book contains some very suggestive charts on forage production in the United States, including timothy, clover, alfalfa, millet, and prairie grass. With all regard to Professor Hitchcock's wide knowledge of grasses, the writer cannot agree fully with the statement that blue grama grass is a short grass and is frequently confused with buffalo grass.

The second part of the book is very much stronger than the first part, in fact, parts of it are rather technical for the average person. A study of it gives one a general idea of our commoner and more valuable grasses. It is not complete enough, however, for the student of grasses to gain a scientific knowledge of the subject. Considerable space is taken up with technical information necessary to the study of grasses. This might well be gained by the college student in one semester's work in general taxonomy, while for the layman who has no knowledge of botany much of this information will be of little value. The writer regrets to say that the citation of reference works in the first part of the book is limited to Washington publications. Some of our best works on forage grasses and grazing ranges have appeared from Experiment Stations in the west. With these faults the book is nevertheless valuable and should be in every general library, and in the libraries of botanists, agrostologists and progressive agriculturists. It can hardly find a place in our schools, however, as a text-book. J. J. THORNBER.

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[1] Hitchcock, A. S., A Text-Book of Grasses. Pp. 276, figs. 63. New York, The Macmillan Company, 1914 ($1.50).

INTERNAL TEMPERATURES OF DESERT PLANTS.—Pearson has investigated[1] the internal temperatures of *Euphorbia virosa* and *Aloe dichotoma*, two of the commonest succulents of Great Namaqualand, carrying on his work in their natural habitat at 4200 ft. elevation. *Aloe* possesses a soft woody stem rich in water. The daily range of temperature at the center of the stem is as much as 24° or even 30° F., the minimum being approximately that of the air, and the maximum only 3° to 7° above atmospheric shade temperature, or up to 101°. *Euphorbia virosa* has a large central air cavity crossed by numerous partitions containing lactiferous vessels. The temperatures of the gas-filled cavities have a daily range of as much as 24° and even 49° F., extending from minima which are practically those of the atmosphere to maxima which are from 19° to 25° higher than those of the air, carrying the internal maximum as high as 125° F. The wounding of *Aloe* causes a tardy fall of temperature, which appears to be due to evaporation from the cut surfaces. The wounding of *Euphorbia* causes an immediate fall of the internal gas temperature, together with a more prolonged local lowering of temperature. The wounding of *Euphorbia* is accompanied by a copious exudation of latex and by a partial release of the internal gas pressure, which is normally somewhat higher than atmospheric pressure. Pearson attributes the sudden fall of temperature to the expansion of the internal gases when released by the wound, and regards the outflow of latex as accelerated by the influence of the pressure disturbances on the lactiferous partitions. Evaporation from the exuded milk causes a local lowering of temperature until the hardening of the surface takes place through formation of caoutchouc. The pressure of the internal gases is suggested as having a function in assisting mechanical ridigity and in increasing the flow of latex. The sealing of wounds by latex in *Euphorbia* is shown to lessen its liability to injurious after-effects, as compared with the non-lactiferous *Aloe*.—FORREST SHREVE.

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[1] Pearson, H. H. W., Observations on the Internal Temperatures of *Euphorbia virosa* and *Aloe dichotoma*. Ann. Bolus Herb. 1: 41–66. Nov. 1914.

## NOTES AND COMMENT

The nineteenth volume of Contributions from the National Herbarium is completely taken up by the 800-page Flora of New Mexico by E. O. Wooton and Paul C. Standley. Much arduous exploration lies at the foundation of this catalogue of the 3000 species of plants which are found in the valleys, plains, deserts, scrub, forest, and alpine summits of this highly diversified state. The usual features of keys to genera and species, citations of synonyms, and statement of type locality are to be found. The statements of range within the state are given in considerable detail and are usually followed by a general statement as to the habitat and zonal distribution of the plant. Critical notes are frequent, and there are also many remarks on the human interest that attaches to certain plants, but is usually severed in works of this character. The Flora contains no description of the vegetation or regional features of the state, such as was found in the floras of Alabama and Washington, published in this series. It is unfortunate that such matter is omitted, for it would be of interest to very many people who will never have occasion to consult the book as it stands. In this case the omission is supplied by the bulletin of Bailey on the Life-Zones of New Mexico (North American Fauna, No. 35), and in part by the bulletin of Wooton on Factors Affecting Range Management in New Mexico (Department of Agriculture, Bulletin 211), in which there is a fine series of illustrations of types of New Mexican vegetation.

In 1908 Mr. George B. Sudworth published a volume of over 400 pages entitled Forest Trees of the Pacific Slope, a book which has been extremely useful to the foresters and botanists of the Pacific region by reason of its very full descriptions, detailed statements of range, and its information regarding growth and climatic requirements. It was the intention of the Forest Service in 1908 to follow this publication by similar ones for the Rocky Mountain region and for the eastern states. This plan has been modified to the extent that these regions will be covered by a series of bulletins, each of which will deal with a small group of genera. The first of the Rocky Mountain series has recently appeared (Department of Agriculture, Bulletin 207), covering the cypresses and junipers. The treatment in this bulletin is less detailed than in the Pacific Slope volume and is more popular, which will make it less valuable to the people—that is to the people who will actually have use for it. The illustrations of the details of foliage and fruit are splendid, but the pictures of the trees themselves are wretched cuts that might well have been replaced by half tones from some of the many fine negatives in the possession of the Forest Service. The distribution of some of the trees is shown by maps, which are executed with painstaking accuracy but are almost too small to be of more than very general use. They are, at least, a poor substitute for the actual lists of occurrence found in the Pacific Slope volume.

Dr. C. C. Adams has published a brief Outline of the Relations of Animals to their Inland Environments, which is an eloquent plea for the dynamic study of animal associations. An extended report by him on the ecology of the invertebrates of prairie and forest is about to appear as a Bulletin of the Illinois State Laboratory of Natural History. In June Dr. Adams entered on his new post as Forest Zoologist in the College of Forestry at Syracuse University, and has since been organizing work on the animal ecology of New York.

# ACID ACCUMULATION AND DESTRUCTION IN LARGE SUCCULENTS

ESMOND R. LONG

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The diurnal variation in the acidity of the sap of succulents has been under investigation for a number of years by Richards.[1] In a large number of observations he has found that the acidity of the expressed juice of cacti is considerably higher in the early morning than at the close of the day, reaching its maximum just before sunrise, and gradually decreasing throughout the day until the minimum is reached approximately two hours before sunset. He has come to the conclusion in view of his experiments and the observations of Spoehr[2] on the photolysis of acids that in the destruction of the acids which accumulate during the night through insufficient oxidation in the catabolism of carbohydrates, both light and temperature play a part. The steps in the photolysis of malic acid, which appears to be the chief acid constituent, other than oxalic acid, in the sap of cacti, have been described by Spoehr,[3] the process being apparently one occurring only in the presence of certain salts and not to be attributed to the action of an enzyme.

In the following experiments the investigations of Richards, in which *Opuntia versicolor* and a number of the flat-jointed opuntias served, have been extended to two of the larger succulent cacti, *Echinocactus wislizeni* (bisnaga) and *Carnegiea gigantea* (sahuaro). The object was not merely to measure the diurnal variation in acidity in these plants, but it was thought that the large diameter of the bisnaga and sahuaro would furnish an admirable opportunity for studying the light and temperature effects upon acidity in different regions of the same plant. A difference of 15°C. was noted in a bisnaga 30 cm. in diameter between the temperature of the tissue just under the epidermis and that of the tissue in the center of the plant at 5 p.m. after a warm day. This is approximately equal to half of the diurnal variation in the temperature of the air at the season in which these experiments were conducted.

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[1] See Annual Report, Carnegie Inst., Wash., 1911, 1912 and 1913.

[2] Annual Report, Carnegie Inst., Wash., 1913.

[3] Ibid, and Biochem. Zeitschr. **57**: (1913), Bd. 1, H. 2, 95–111.

The material for this investigation was all obtained from the eastern slope of the Tucson Mountains within a radius of three or four miles from the Desert Laboratory. The method adopted in the analysis was as follows: Only as many plants as could be studied in three or four days were secured at one time. These were exposed one at a time to the sunlight throughout the day and split longitudinally late in the afternoon, the half which had been most exposed being taken for analysis immediately, the other being laid aside for analysis in the early morning. The latter portion was laid cut surface down on a flat table so that as little evaporation as possible might take place from the injured surface, and in the morning the further precaution was taken of cutting away about an inch of this surface layer, which would be as deep as any abnormal evaporative or oxidative action of the air might have occurred. The actual analysis was made in this manner: Sample portions were taken at a uniform distance from the base,[4] from each split plant and numbered as indicated in figure 1. A and B were close together and taken within the ridges of the plants, A just inside of the chlorophyll bearing tissue, B a little deeper. A and B were thus from a region much more exposed to light and heat than the other samples and A in turn more than B. These relations are indicated in the diagrams of the plants cut in cross section. The samples thus obtained were pressed out in a fruit press and the products warmed rapidly and titrated against $\frac{N}{10}$ NaOH with phenolphthalein as indicator. In the tables to follow, the acidity of the sap, which was determined by the titration of 25 cc. samples, is recorded in the number of cc. of $\frac{N}{10}$ NaOH required to neutralize 1 cc. of the sap.

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[4] MacDougal and Spalding, Carnegie Inst., Wash., (Publ. 141) have shown that the proportion of sap to dry tissue varies considerably within the same plant in the sahuaro and bisnaga, the water content being greatest near the apex of the trunk and least at the base.

The increase in acidity in the morning samples is apparent. This is what is to be expected in view of the greater intensity of light and heat acting upon the plants during the day. Relieved from the destructive action of these agencies, the organic acids which are formed wherever carbohydrates are being burned, tend to accumulate during the night faster than they are de-

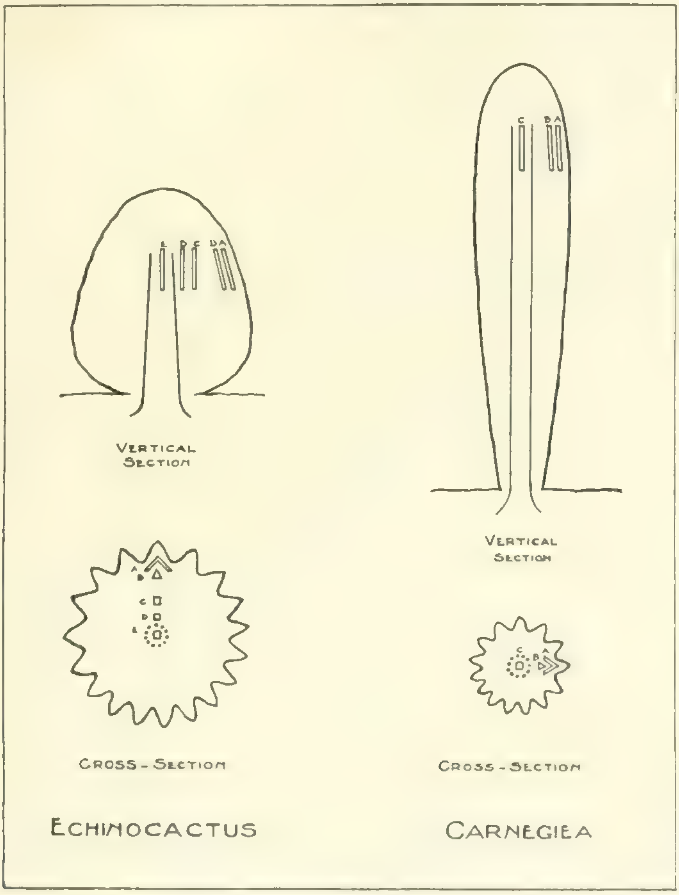

Fig. 1. Diagram of *Echinocactus* and *Carnegiea* in section, showing regions from which samples were taken for analysis.

stroyed, while in the day the reverse process takes place, so that the acidity of the sap is higher at the day's beginning than at its close.

It would be expected furthermore that the accumulation of acidity during the night would be the greatest where the concentration of carbohydrates is greatest, that is in the outer parts near the chlorophyll tissue, the seat of carbohydrate formation, and this is confirmed by the analytical tests. Taking the figures from table 1 and subtracting the late afternoon value for acidity from that of the early morning, we obtain the results shown in table 2.

TABLE 1

*Showing dry weight (in per cent), density of sap, and acidity of sap in three samples at different depths from each of three plants of Carnegiea. All plants collected July 18; analyses made at 5 p.m. on July 18, 19, and 21, and at 8 a.m. on the mornings following. Plant No. 1: height 126 cm., sampled 70–90 cm. from base; No. 2: height 134 cm., sampled 80–100 cm. from base; No. 3: height 110 cm. sampled 55–75 cm. from base*

| PLANT | SAMPLE | 5 P.M. | | | 8 A.M. | | |
|---|---|---|---|---|---|---|---|
| | | Dry wt | Density | Acidity | Dry wt | Density | Acidity |
| No. 1..... | A | 10.1 | 1.013 | 0.404 | 9.1 | 1.014 | 0.492 |
| | B | 5.9 | 1.010 | 0.324 | 7.4 | 1.012 | 0.388 |
| | C | 11.6 | 1.014 | 0.148 | 12.6 | 1.015 | 0.172 |
| No. 2..... | A | 11.4 | 0.980* | 0.368 | 9.4 | 0.987 | 0.556 |
| | B | 8.6 | 1.008 | 0.408 | 8.2 | 1.010 | 0.456 |
| | C | 10.7 | 1.012 | 0.268 | 12.2 | 1.013 | 0.304 |
| No. 3..... | A | 5.5 | 1.008 | 0.544 | 6.1 | 1.009 | 0.616 |
| | B | 4.9 | 1.009 | 0.452 | 5.5 | 1.009 | 0.524 |
| | C | 5.7 | 1.009 | 0.320 | 6.4 | 1.008 | 0.300 |

* Large amount of air in sap.

The difference between morning and evening acidity is thus seen to be relatively great in the outer parts and slight in the central tissues. This is probably to be explained as follows. Near the surface of the plant, where soluble carbohydrates are plentiful, we have a relatively large carbohydrate metabolism as compared with the inner tissues, which because of their distance from the source of soluble carbohydrates, receive their supply slowly and are therefore limited to a smaller carbohydrate metabolism, so that acid production is less rapid than near the surface. Furthermore, as the center of the plant is approached, the increasing insulation tends to minimize temperature and light differences of night and day. Briefly stated there is a large accumulation of acids during the night in the outer parts and a large destruction of acids during the day, so that diurnal differences in acidity are large, while in the inner parts there is much slower formation of acids and only a slight diurnal difference in the action of light and heat upon them, so that diurnal differences here are small.

TABLE 2

*Showing differences in the acidity of sap in samples taken in afternoon and morning at different depths from plants of Carnegiea collected July 18*

| PLANT | TIME | SAMPLE A | SAMPLE B | SAMPLE C |
|---|---|---|---|---|
| No. 1 | 8 a.m. | 0.492 | 0.388 | 0.172 |
| | 5 p.m. | 0.404 | 0.324 | 0.148 |
| | | 0.088 | > 0.064 | > 0.024 |
| No. 2 | 8 a.m. | 0.556 | 0.456 | 0.304 |
| | 5 p.m. | 0.368 | 0.408 | 0.268 |
| | | 0.188 | > 0.048 | > 0.036 |
| No. 3 | 8 a.m. | 0.616 | 0.524 | 0.300 |
| | 5 p.m. | 0.544 | 0.452 | 0.320 |
| | | 0.072 | = 0.072 | > −0.020 |

In the protocols to follow it will be seen that the same conditions exist in the bisnaga (tables 4 and 5).

The facts expressed in the accompanying tables agree in the main with those outlined above in the case of the sahuaros. Bisnagas 28, 29, 32 and 33 are distinctly more acid in the early morning than in the late afternoon and with only one partial exception the difference in acidity of corresponding samples of the two periods progressively becomes smaller as the center of the plant is approached. In bisnaga 29 the increase in morning acidity over preceding afternoon acidity, is greater in the case of B than in A. It is probable that the lateness of the hour of analysis (9 a.m.) is partly responsible for this condition, *i.e.*, that the photolysis of acid in A was already under way. From B to D the usual condition of a progressive decrease in the subtraction value, is observed, until at D the acidity of morning and afternoon sap is practically the same. Bisnaga No. 27 presents a contrast to all the other specimens studied in that the sap of A is more acid in the afternoon than in the early morning, and the subtraction value becomes larger instead of smaller as the center is approached. No satisfactory explanation can be given for this discrepancy. Apparently metabolism was not very active, for the differences between day and night acidity are not great at any point. Owing to adverse weather conditions early morning analyses were not made of Nos. 30 and 31, these being included in the protocols merely to show some other relations of interest in the general discussion.

## DISCUSSION

A glance at the tables shows a constant feature with regard to the water distribution. In morphologically similar tissue, that is from A to D inclusive in the bisnaga and in A and B in the sahuaro, the dry weight of the tissue decreases as the center is approached. (E of the bisnaga and C of the sahuaro, each within the fibro-vascular cylinder of the plant are more woody than the tissues peripheral to the ring and are characterized by a relatively low water content and low acidity.) This is presumably the result of an active transpiration in which water is removed from the superficial tissues more rapidly than it is supplied by conduction and diffusion from the interior. It would be expected that in the nightly checking of transpiration the outer tissues would tend to "catch up" in water content at the expense of the inner ones, that is, that the inside tissues would become drier and the outside ones wetter during the night, and that the morning analysis would show a more even distribution of the water than in the preceding evening. And this is actually found to be the case

TABLE 3

*Showing dry weight (in per cent) and acidity of sap in four samples at different depths from each of seven plants of Echinocactus. Plants 27 to 29 collected June 30; Plants 30 to 32 collected July 8; Plant 33 collected July 18*

| PLANT | WEIGHT | DATES AND HOURS | SAMPLE | AFTERNOON | | MORNING | |
|---|---|---|---|---|---|---|---|
| | | | | Dry wt. | Acidity | Dry wt. | Acidity |
| | kg | | | | | | |
| No. 27 | 20 | June 30–July 1 | A | 11.9 | 0.376 | 10.0 | 0.342 |
| | | 4 p.m., 8 a.m. | B | 10.7 | 0.269 | 9.0 | 0.278 |
| | | | C | 7.7 | 0.154 | 7.5 | 0.166 |
| | | | D | 6.7 | 0.143 | 7.1 | 0.166 |
| No. 28 | 12 | July 1–July 2. | A | 11.1 | 0.145 | 10.6 | 0.184 |
| | | 3 p.m., 9 a.m. | B | 9.0 | 0.142 | 9.4 | 0.168 |
| | | | C | 7.5 | 0.147 | 7.7 | 0.172 |
| | | | D | 6.8 | 0.152 | 7.2 | 0.168 |
| No. 29 | 25 | July 4–July 5. | A | 12.1 | 0.400 | 10.9 | 0.472 |
| | | 4 p.m., 9 a.m. | B | 9.2 | 0.320 | 9.1 | 0.472 |
| | | | C | 7.4 | 0.196 | 5.9 | 0.256 |
| | | | D | 7.1 | 0.166 | 6.6 | 0.180 |
| No. 30 | 17 | July 8*. | A | 10.0 | 0.136 | | |
| | | 3 p.m. | B | 9.3 | 0.144 | | |
| | | | C | 7.8 | 0.216 | | |
| | | | D | 7.3 | 0.212 | | |
| No. 31 | 20 | July 9*. | A | 8.2 | 0.124 | | |
| | | 3 p.m. | B | 6.5 | 0.120 | | |
| | | | C | 4.7 | 0.100 | | |
| | | | D | 4.3 | 0.088 | | |
| No. 32 | 15 | July 10–July 11. | A | 6.0 | 0.156 | 6.4 | 0.232 |
| | | 4 p.m., 7 a.m. | B | 5.3 | 0.180 | 4.7 | 0.208 |
| | | | C | 3.9 | 0.192 | 3.3 | 0.192 |
| | | | E | 9.6 | 0.120 | | |
| No. 33 | 12 | July 21–July 22. | A | 8.0 | 0.140 | 6.4 | 0.256 |
| | | 6 p.m., 7 a.m. | B | 6.6 | 0.176 | 5.1 | 0.232 |
| | | | C | 5.9 | 0.236 | 4.6 | 0.192 |

* Because of heavy rains during the night, which probably affected the plants through the exposed surface, morning analyses were not made.

in most of the plants studied. For example, the difference in water content of A and B in sahuaro No. 1 is 4.2 per cent (of the wet weight of the plant) at 5 p.m., and only 1.7 per cent at 8 a.m.

the next morning. Similar calculation for all the plants examined gives the results shown in table 5 for the varying water content.

If we assume that at a given time of day two halves of the plant are similar in water distribution, and this is probably fair in view of the symmetry of these plants, then the above figures simply show that generally the difference between the water content of the external and internal simply diminishes during the night. During the day water evaporates from the surface more rapidly than it can be supplied by conduction and diffusion from the internal parts. The lost water of the surface layer is replaced again at the expense of the interior (which by the excision of the plant was cut off from its water supply) during the night. Thus we may conclude from the general observation that the water

TABLE 4

*Showing differences in the acidity of sap in samples taken in afternoon and morning at different depths from plants of Echinocactus collected June 30, July 8, and July 18*

| PLANT | TIME | SAMPLE A | SAMPLE B | SAMPLE C | SAMPLE D |
|---|---|---|---|---|---|
| No. 27 | 8 a.m. | 0.342 | 0.278 | 0.166 | 0.166 |
| | 4 p.m. | 0.376 | 0.269 | 0.154 | 0.143 |
| | | −0.034 | < 0.009 | < 0.012 | < 0.023 |
| No. 28 | 9 a.m. | 0.184 | 0.168 | 0.172 | 0.168 |
| | 3 p.m. | 0.145 | 0.142 | 0.147 | 0.152 |
| | | 0.039 | > 0.026 | > 0.025 | > 0.016 |
| No. 29 | 9 a.m. | 0.472 | 0.472 | 0.256 | 0.180 |
| | 4 p.m. | 0.400 | 0.320 | 0.196 | 0.166 |
| | | 0.072 | < 0.152 | > 0.060 | > 0.014 |
| No. 32 | 7 a.m. | 0.232 | 0.208 | 0.192 | |
| | 4 p.m. | 0.156 | 0.180 | 0.192 | |
| | | 0.076 | > 0.028 | > 0.000 | |
| No. 33 | 7 a.m. | 0.256 | 0.232 | 0.192 | |
| | 6 p.m. | 0.140 | 0.176 | 0.236 | |
| | | 0.116 | > 0.056 | > −0.044 | |

content of the outer parts is higher (while that of the inner is lower) in the morning than in the preceding evening.

Obviously this movement must be taken into consideration in a study of acidity. Since the dissolved acids of the interior sap will be carried along in the stream, they will tend to accumulate in the outer parts and thus increase their total acid content. The main features of the conducting system of the sahuaro and bisnaga are a central, woody, fibrovascular cylinder, with ramifications extending from it to the chlorophyllous tissue.

With such an extensive conducting system changes in the acidity of different zones due to movement of fluids might be expected. However as closer consideration and a study of the last tables will show, this effect is not marked. The amount of acid carried to the outer parts by conduction from the inner must be in proportion to the water, and the net result might be an increase or decrease in the acidity per cc. of the outer sap, according as the sap of the interior had a higher or lower concentration than that of the exterior. However the increase of water content in a given area by movement from neighboring interior tissue is only 1 to 3 per cent (see tables on a.m. and p.m. water distribution), while the morning acidity may exceed that of the preceding afternoon by as much as 50 per cent. It would seem therefore that sap movements play a very small part in the case in question and we may safely assume that the observed effects are due to nightly accumulation and daily destruction of the acid products of carbohydrate metabolism. As a glance at the tables will show, diurnal differences in the density of the sap are so slight as to be negligible.

One point to consider further is the relatively high concentration of acid observed in the outer parts in the early morning analysis. The acidity near the surface is often double or even triple the acidity of the sap at the center and usually becomes progressively lower as the center is approached. While no estimations of sugar concentration were made, it seems probable that this higher acidity in the outer parts is due to a higher concentration of carbohydrates in the same regions. The synthesis of carbohydrates can take place only in the green tissue of the

TABLE 5

*Showing differences in water content (in per cent) in samples taken in afternoon and morning at different depths from plants of Carnegiea (C) and Echinocactus (E)*

| PLANT | SAMPLE | AFTERNOON | MORNING | PLANT | SAMPLE | AFTERNOON | MORNING |
|---|---|---|---|---|---|---|---|
| C 1...... | B | 94.1 | 92.6 | E 29.. | B | 90.8 | 90.9 |
| | A | 89.9 | 90.9 | | A | 87.9 | 89.1 |
| | | 4.2 > | 1.7 | | | 2.9 > | 1.8 |
| C 2...... | B | 91.4 | 91.8 | | C | 92.6 | 94.1 |
| | A | 88.6 | 90.6 | | B | 90.8 | 90.9 |
| | | 2.8 > | 1.2 | | | 1.8 < | 3.2 |
| C 3...... | B | 95.1 | 94.5 | | D | 92.9 | 93.4 |
| | A | 94.5 | 93.9 | | C | 92.6 | 94.1 |
| | | 0.6 = | 0.6 | | | 0.3 > | −0.7 |
| E 27. | B | 89.3 | 91.0 | E 32 . | B | 94.7 | 95.3 |
| | A | 88.1 | 90.0 | | A | 94.0 | 93.6 |
| | | 1.2 > | 1.0 | | | 0.7 < | 1.7 |
| | C | 92.3 | 92.5 | | C | 96.1 | 96.7 |
| | B | 89.3 | 91.0 | | B | 94.7 | 95.3 |
| | | 3.0 > | 1.5 | | | 1.4 = | 1.4 |
| | D | 93.3 | 92.9 | E 33 . . | B | 93.4 | 94.6 |
| | C | 92.3 | 92.5 | | A | 92.0 | 93.6 |
| | | 1.0 > | 0.4 | | | 1.4 > | 1.0 |
| E 28. . . | B | 91.0 | 90.6 | | C | 94.1 | 95.4 |
| | A | 88.9 | 89.4 | | B | 93.4 | 94.6 |
| | | 2.1 > | 1.2 | | | 0.7 < | 0.8 |
| | C | 92.5 | 92.3 | | | | |
| | B | 91.0 | 90.6 | | | | |
| | | 1.5 < | 1.7 | | | | |
| | D | 93.2 | 92.8 | | | | |
| | C | 92.5 | 92.3 | | | | |
| | | 0.7 > | 0.5 | | | | |

surface, which in the sahuaro and bisnaga is approximately 5 mm. in thickness, so that the cells of the rest of the plant are dependent for their carbohydrate nutriment upon diffusion and conduction from the exterior. It seems logical to suppose, as long as metabolism is continuous and no storing up takes place, that the further an area is from its source of supply of sugars the lower its concentration of sugar will be. And as the sugars are continually being broken down with the production of acids the concentration of the latter will be greatest where the sugar concentration is greatest, that is, near the exterior of the plant. It will be noticed in the tables that the situation is frequently reversed at the close of the day, that is, that the acidity is greatest in the interior and decreases toward the exterior, this being due as explained above, to the daytime destruction of accumulated acids. But it is significant that the nightly accumulation of acid always leads to a higher acidity of the exterior than of the interior.

## SUMMARY

The acidity of the sap of *Echinocactus wislizeni* and *Carnegiea gigantea* is higher in the early morning than at sunset, the acids formed in the metabolism of carbohydrates tending to accumulate during the night and being partially destroyed by higher temperature and photolysis in the succeeding day. The acidity of the sap of these species following the nightly accumulation of acid is higher in the outer than in the inner regions. This higher acidity is probably resultant from a higher concentration of sugar in the outer parts, that is, in the region of sugar formation. The diurnal difference in acidity of the sap becomes smaller in successive zones as the center of the plant is approached, being as much as 50% in the exterior and slight in the innermost tissues. In the outer parts where carbohydrates are plentiful, sugar metabolism is great and acid production and nightly acid accumulation are large; these parts are on the other hand the most exposed to the action of light and heat, so that the daily destruction of acid is great. Accordingly here diurnal differences in acidity are large. In the innermost tracts of tissue carbohydrates are

less plentiful, acid production is correspondingly less, and the increasing insulation as the center is approached tends to minimize diurnal temperature and light differences, so that in these parts diurnal differences in acidity are small. The movement of sap of low acidity from the central cylinder to the peripheral layers of these thick succulents has little effect upon the acid content of these tracts, while variations of great amplitude result from the conjoint action of light and temperature.

# A STUDY OF THE ROOT-SYSTEMS OF PRAIRIE PLANTS OF SOUTHEASTERN WASHINGTON

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(Concluded)

## II.

### *Agropyron spicatum (including var. inerme) (Fig. 10)*

This is the most common bunchgrass in eastern Washington. It has its best development westward of the high upland prairies of extreme eastern Washington and along the rim-rock through the eastern part. The bunches are often 10 inches in diameter and reach a height of over 3 feet. As many as 300 to 350 individual stems may occur in a single bunch. The plant blossoms in June and dries out in early July, only to take on renewed growth after the autumn rains, and remain green all winter. Figure 10 shows *Agropyron* on the rim-rock with its roots penetrating the rock crevices to depths of 45, 46 and 48 inches. Ten plants were examined under these conditions. The roots of all followed the cleavage planes of the basalt on an average to a depth of 4 feet and 1.3 inches, but one extended along the deeper moist crevices to a depth of 5 feet.

In the well-developed highland prairies the bunch habit is partially abandoned and long rhizomes are produced. The clumps are always much smaller here, perhaps only a few centimeters wide, but there are usually as many as 5–6 per square meter. Twelve prairie *Agropyrons* were examined. This grass has coarser roots than any of the other three important native grasses. These coarse, fibrous roots have many short laterals. Some of these roots reach a depth of 4 feet and 9.5 inches, although on an average 4 feet and 2 inches was the greatest depth attained. Five plants on a southwest slope gave an average depth of 4 feet and 1.6 inches, while seven on a northwest slope reached an average depth of only 3 feet and 2.6 inches.

### *Festuca ovina ingrata* (*Fig. 11*)

The blue bunchgrass ranks in importance with *Agropyron spicatum* on the well-developed high prairies west of the foothills of the Bitter-root Mountains between Spokane, Washington, and Lewiston, Idaho. Because of its abundance (often 10–13 bunches per square meter), the very appropriate name Palouse (Fr. *Pelouse*, a land clothed with a short, thick growth of herbage)

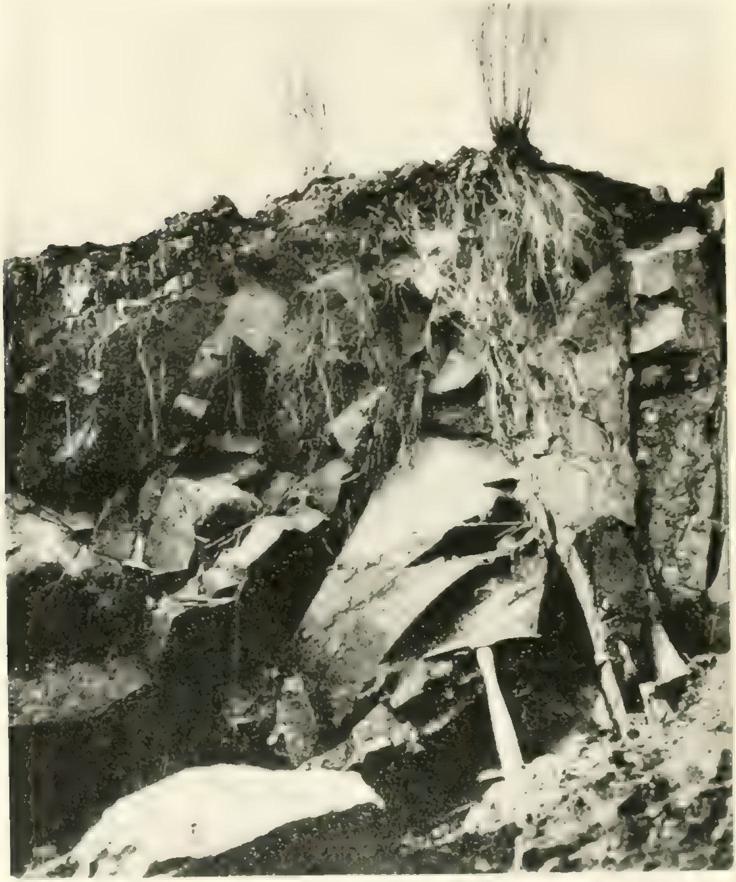

Fig. 10. *Agropyron spicatum* growing on the rim-rock and securing its water supply from the moist rock crevices of the broken basalt.

was early applied to the region. The slightly pale green plants are densely tufted into bunches from 1 to 4 inches in diameter, and, while the numerous setaceous leaf blades are mostly basal and about 12 inches high, the stems which bear flowers reach a height of 12 to 18 inches. The whole plant dries out considerably by the middle of July, but the autumn rains revive it, and it is green throughout the rest of the year.

*Festuca ovina* has a great mass of jet black roots which occupy the soil thoroughly from the surface to a depth of about 18 inches, below which depth relatively few roots extend. None of the roots are over one millimeter in diameter. They branch profusely to the third order mostly, and the laterals are usually less than an inch in length. This branching continues to the very tip, and there the laterals are usually longer. Twenty-two plants were examined. The longest root found was 3 feet and 3 inches, the average length 2 feet and 1.5 inches for the deepest roots, but the great bulk of roots were less than 18 inches long. All the plants examined were on a southwest slope.

### *Poa sandbergii* (*Fig. 11*)

Sandberg's Poa is one of the earliest plants to gain a foothold upon the thin rocky soil of the scab-lands, and along the rim-rock. It grows in small tufts usually only from 0.5 to 1.5 inches wide, puts out new roots when the fall rains begin, grows throughout the winter and spring, and evades drought by flowering late in May or in early June, and remaining dormant the rest of the growing season. On the prairies it is an interstitial plant, often as many as 30 40 small tufts occurring in a single square meter on the dry south slopes.

*Poa* has smaller roots than *Festuca ovina ingrata*, they are more profusely branched, and the fine laterals which are short (usually less than 1 inch) are more numerous, smaller, and much more branched. The creamy-white roots spread laterally 3 to 5 inches and occupy thoroughly the first few inches of soil, relatively few extending below a depth of 8 inches, and none were found beyond 13 inches. The root branches are longer and more numerous at the tip than are those of *Festuca*. *Poa* roots branch to the fourth order. Six plants were examined on the rim-rock with an average root depth of 7.2 inches. Eight prairie species of *Poa* growing on a southwest slope gave an average maximum depth of 9.7 inches.

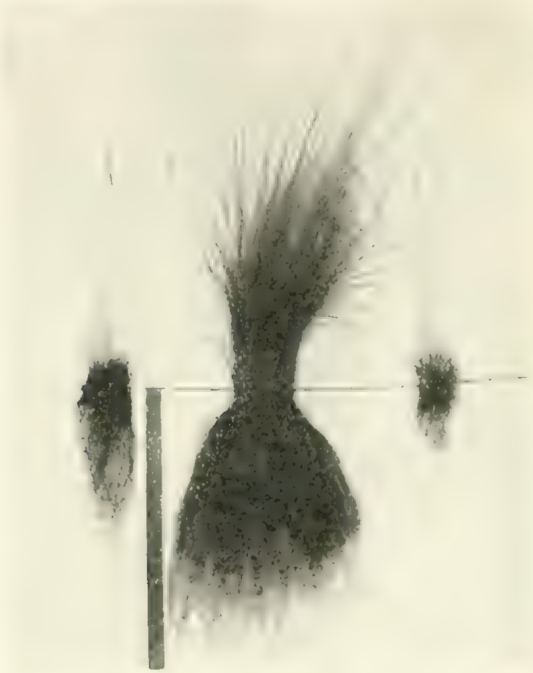

Fig. 11. Three imporant prairie grasses. *Koeleria cristata* (to the left), *Festuca orina ingrata* (center), and *Poa sandbergii*. All are relatively shallow rooted.

### *Koeleria cristata*. (*Fig. 11*)

This is a very common bunchgrass on the prairies of eastern Washington, not infrequently occurring as abundantly as 6 clumps per square meter. However, the bunches are smaller in diameter (0.5 to 2 inches, usually) than those of *Festuca orina ingrata*, and also of less height (1 2.5 feet) than *Agropyron spicatum*. *Koeleria* flowers in late June or early July and like *Poa* remains dormant until revived by the autumn rains.

The roots, which are a dirty-gray in color, resemble those of *Agropyron* but taper down faster, and have finer laterals which branch mostly to the third order. These laterals, like those of the shallow rooted *Poa*, are more numerous than in *Agropyron*. Six plants were examined. The deepest root found was at 28 inches, and 15 inches was determined as the average maximum depth.

### *Balsamorhiza sagittata* (*Fig. 12*)

The balsam root is, with the exception of *Agropyron spicatum* and *Festuca ovina ingrata*, the most characteristic plant of the high prairies of eastern Washington. Its abundance, size, and duration all unite to make it a very important ecological species. It is not unusual to find a dozen of these plants in an area of 4 square meters. Only on the steeper northeast slopes and wet valleys is it absent. A medium sized mature plant occupies an area of 4–5 square feet, may have as many as 50–80 of the large sagittate leaves, and a total leaf surface of 30 square feet. From the short, thick, multicipital stem (I have counted 39 individual shoots on a stem 9 inches in diameter) the new leaves appear in April. By the first of May the plant is often in full bloom and is the most conspicuous member of the vernal aspect which lasts until about June 1st. After this the whole aerial part dries up, but the dead leaves are conspicuous throughout the year.

Twenty-five root-systems were excavated and examined. *Balsamorhiza* has a tap root sometimes reaching a diameter of 4 inches and an extreme depth of 8 feet and 10 inches. The laterals seldom come off in the first 6 inches of soil, but below this numerous strong laterals occur, sometimes 1 inch or more in diameter, and these often run rather horizontally for 2 or 3 feet before they turn downward. They may ultimately reach depths of 5 feet or more. The lateral branching is profuse, and in all directions the soil is laid hold upon. Sometimes the tap splits up into nearly equal parts at a depth of a few feet. The tip of the tap root is often dead, and, if alive, never much branched. Small branch orders near the tip are not abundant. The older part of the root especially is covered with a deeply furrowed bark. These furrows in old roots are sometimes 0.5 inch deep. The taste is characteristic, and a balsam-like substance exudes from the old roots when injured. Five feet and 6.1 inches was determined as the average root depth. Nine plants on a southwest slope gave an average depth of 5 feet and 1.5 inches; fourteen on a northwest slope, 5 feet and 9.8 inches, and two on a northeast slope, 5 feet.

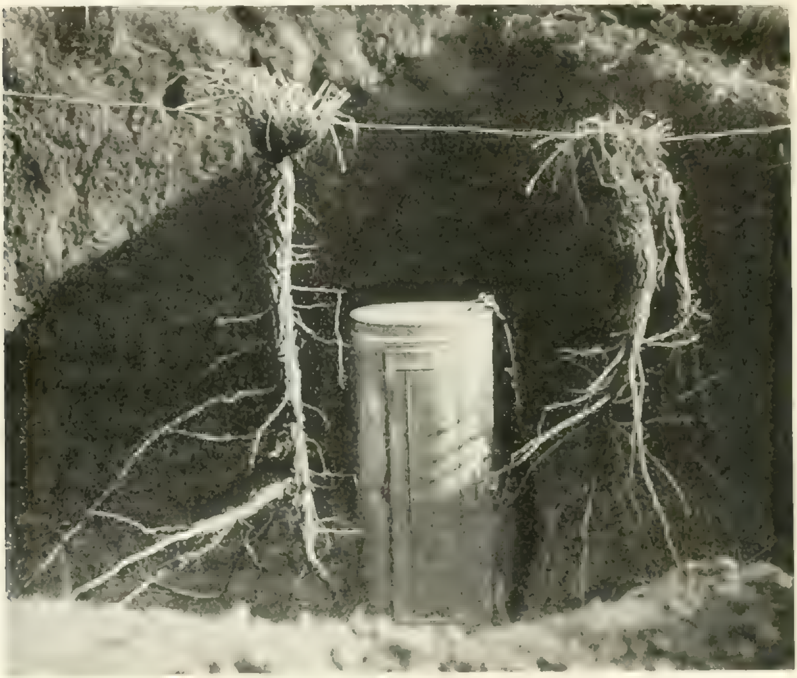

Fig. 12. Two roots of *Balsamorhiza sagittata* partially uncovered and photographed in place. Note the deeply furrowed bark and extensive system of laterals.

### *Geranium viscosissimum* (*Geranium incisum*) (*Fig. 13*)

Just as *Balsamorhiza* is characteristic of dry slopes, so *Geranium* is found most abundantly on moist northeast hillsides and in the valleys. It seldom occurs abundantly on exposed hillsides. *Geranium* is a large plant reaching a height of from 20 to 30 inches, with a wide spreading top which often covers an area of 4 to 5 square feet. It begins blossoming in late May or early June, and its large red flowers (sometimes as many as 80 to 100 in bloom at one time on a single plant) are conspicuous in the estival aspect especially of moist situations. By the second week in July blossoming ceases, but the plant often remains green till late into the summer, if not all fall.

*Geranium* has a well-developed tap root which may reach three inches in diameter. It is often more or less decayed and may split up into two or more parts, thus giving rise to new plants. The tap sends off many laterals both large and small at all levels, all of which may branch profusely to the fifth order. The larger laterals usually run off in a horizontal direction, sometimes for nearly 3 feet before turning downward. The end of the tap root is either unbranched or branched but little, and is often dead. The bark is reddish and scaly on the older parts. Hard soil seems to be a marked limiting factor to root growth, and under this condition especially the usual very irregular course of descent is greatly emphasized. Twenty-four root-systems were examined. The greatest root depth, 9 feet and 6 inches, was reached on a northwest slope, and an average depth of 5 feet and 3.4 inches was determined. Thirteen plants on a northeast slope gave an average root depth of 4 feet and 8.1 inches, while eleven on a northwest slope reached an average depth of 6 feet and 0.2 inch.

### *Wyethia amplexicaulis* (*Fig. 14*)

The black sunflower, at home in the moist meadows, also often occurs on rather dry hillsides. Like *Balsamorhiza*, it is large and abundant and of considerable duration, being conspicuous even after drying out, but, unlike it, its distribution on the high prairies is local and patchy. When we recall that a single plant may have from 14 to 31 leaves, each from 3 to 5 inches in greatest diameter and from 13 to 17 inches in length, the enormous transpiring surface may be realized. This shiny, resinous, dark green plant blossoms during the last week of May or the first week of June and rapidly dries up in early July. The numerous large yellow flowers 2.5–3 inches in diameter make these societies very conspicuous.

The fleshy tap root sometimes measures 9 inches in circumference and may reach a depth of 6 feet and 5 inches. It usually has several strong laterals which come off from 8 inches to 3 feet in depth, and may run out in a somewhat horizontal direction for 3 or 4 feet from the main root. Sometimes, however, only a single lateral occurs. Often at a depth of 1–3 feet the whole tap breaks up into 2–5 nearly equal parts which pursue a downward course, or later extend out as laterals. Primary laterals are not much branched. The whole root from crown to near the tip is covered with scattered small laterals usually not over 2 milli-

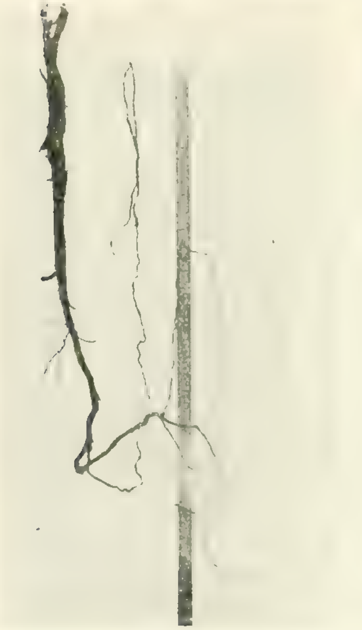

Fig. 13.

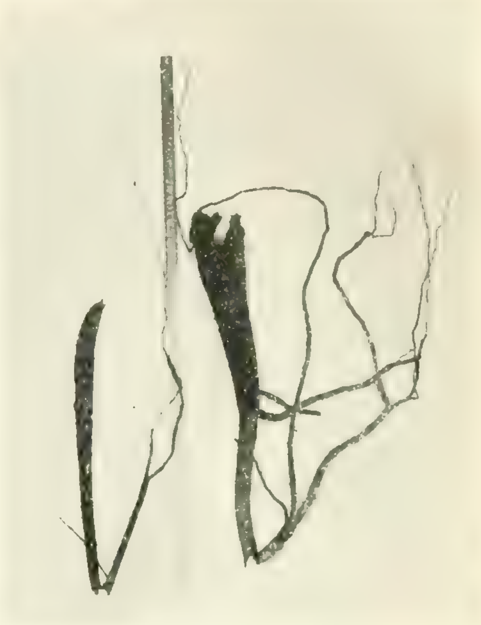

Fig. 14.

Fig. 13. *Geranium viscosissimum.* The crown is partly decayed. The roots are so brittle that they are removed from the soil with extreme difficulty. Five hours were spent in securing the above specimen.

Fig. 14. Two roots of the black sunflower, *Wyethia amplexicaulis.* Note the numerous short laterals.

meters in diameter. These are poorly branched, not often giving off roots of the fourth order. The tip of the main root likewise is little branched. The roots are black externally, grayish inside, have a characteristic odor, and dry out and shrink rapidly upon removal from the soil. Eighteen plants on a northeast slope were examined. They had an average root depth of 5 feet and 0.4 inch.

### *Heuchera glabella*

This plant, so characteristic of the rim-rock crevices especially on the more moist exposures, also occurs rather frequently (often 2 or 3 per square meter) on moist slopes in the prairie. The tufted radical leaves mostly remain green all winter. It belongs to the estival aspect. An examination of seven plants gave an average root depth of 5 feet and 1.4 inches. One root reached a depth of 5 feet and 11 inches. The strong tap is triangular in section near the top and often retains this shape to a depth of 2 feet. The laterals, which are quite numerous, usually come off in the first foot of soil. The root-system as a whole is poorly branched, even the root tips are poorly supplied with branches.

### *Leptotaenia multifida*

This large, much branched, umbelliferous plant occurs quite commonly on both dry and moist hillsides. The great ternately decompound, pinnatifid leaves, together with the main stems which stand up well above other prairie vegetation, are very conspicuous even when the plants are not abundant, and especially so in June, when after flowering, the leaves turn yellow before drying up.

Fourteen root-systems were examined, mainly incidentally while excavating other roots. These large fleshy roots are sometimes 7 inches in circumference and may reach a depth of 5 feet and 7 inches. The fusiform roots may narrow down gradually or rather abruptly, even to a diameter of one or two millimeters and then again enlarge at a greater depth to a size equalling the original. This is sometimes repeated several times, thus giving the root as a whole a beaded appearance. In general the roots are very poorly branched. Ten plants on a northwest slope gave an average depth of 3 feet and 11.3 inches, while five on a northeast slope reached an average depth of 4 feet and 6.7 inches, thus giving a total average root depth of 4 feet and 0.7 inch.

### *Helianthella douglasii* (*Fig. 15*)

This and the following composite are both important and abundant prairie species. They occur typically on dry hillsides, often as many as 2 8 per square meter. While *Helianthella* adds much to the estival prairie aspect, with its large yellow flowers, its blossoming period is well past when *Hoorebekia racemosa* comes into bloom in late July. The latter is one of the few species giving tone to a poorly defined autumnal aspect.

*Helianthella* has a tap root with a diameter seldom more than 0.8 inch. It throws out many big laterals just beneath the surface, most of which come off within the first 18 inches of soil, although there are some lower, and a cone may be formed all the way to the tip. The laterals usually pursue rather a vertically downward course, and are profusely branched. *Helianthella* branches more at the tip than does *Hoorebekia*, and it also throws out more laterals than that species. The roots are reddish-brown in color, those of *Hoorebekia* are white. They have a strong, characteristic odor, and an oily taste slightly resembling carrots. By these characters it is easy to distinguish *Helianthella* roots from others. Twenty plants were examined. An average depth of 4 feet and 4.5 inches was found; the deepest-rooted plant exceeding this by only 12.5 inches. Six plants on a southwest slope gave an average root depth of 4 feet and 4 inches; five on a northeast slope 4 feet and 8.6 inches; and ten on a northwest slope 4 feet and 7.1 inches.

### *Hoorebekia* (*Aplopappus*) *racemosa* (*Fig. 16*)

Thirty-four plants were examined. The deepest roots reached 7 feet and 7 inches, and 11 feet respectively, but the average depth was 5 feet and 5 inches. *Hoorebekia* has a strong tap root which tapers gradually to the end. The larger laterals (if any) are often thrown off within the first 18 inches of soil. These are branched to the third order, and may run off in a rather horizontal direction. The tap grows directly downward and is sparingly branched all the way to and at the tip. The main root is not usually more than 0.5 inch in diameter. It changes in color from light yellowish near the surface to nearly white below three feet. It has a sharp bitter taste and lacks the odor so characteristic of *Helianthella* roots. Twelve roots on a northeast slope averaged 5 feet and 3.4 inches in depth; twelve on a southwest slope 5 feet and 4 inches; and ten on a northwest slope 5 feet and 8.2 inches.

### *Lithospermum ruderale*

These plants occur as isolated individuals, but their large size, densely tufted leaves, and numerous if not showy flowers, make them conspicuous objects in the bunchgrass association of the rim-rock as well as in the prairie.

Five root-systems were examined. The large tap roots, from 3 to 10 inches in circumference, give promise of deeper root-systems than are actually attained. Only one plant reached a depth of 6 feet and 3 inches, and the average depth was only 4 feet and 10.3 inches. Large laterals were sent off from the main root at various depths from 1 to 2 feet. These ran horizontally several feet before turning downward. One main root curved and twisted a great deal finally ending 3 feet northwest of the place where it started. The tip of the largest root examined had decayed. These roots have a very thick cortex, which separates easily from the stele. The outer part of the cortex is bright reddish especially on the parts below 1 foot. The old root bark is shreddy and gray, but firm. A peculiar taste and odor characterize these roots. Two plants on a northwest slope each reached a depth 16 inches greater than any examined on north or south slopes.

### *Sieversia ciliata*

The soft hairy, tufted, radical leaves of *Sieversia* often remain green throughout the winter. The simple erect stems reach a height of 12–18 inches and bear their blossoms in late May or early June, while in late July or the first of August the aerial plant parts largely dry up. This is a common, abundant, and cosmopolitan prairie species.

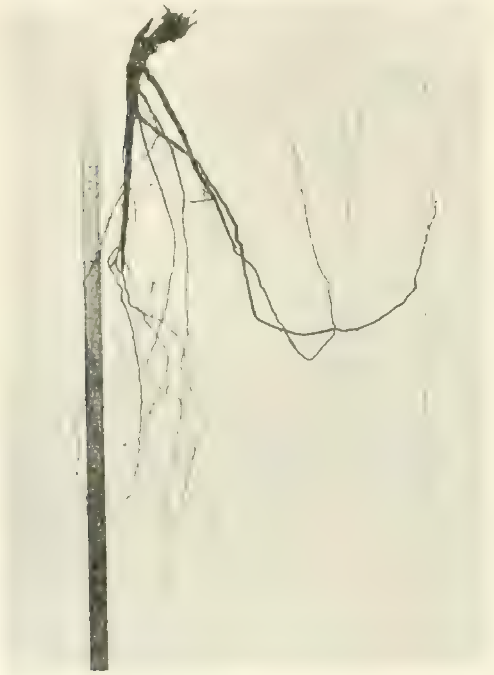

Fig. 15.

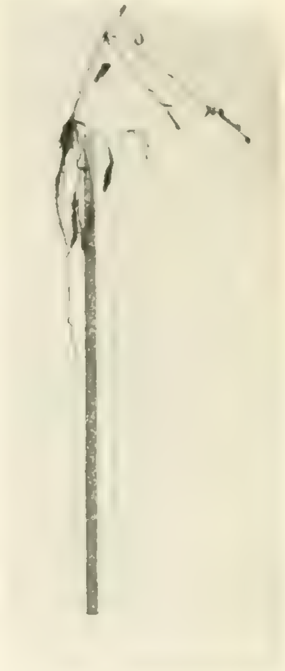

Fig. 16.

Fig. 15. Root-system of *Helianthella douglasii*. It may be noted that the tap root was decayed.

Fig. 16. *Hoorebekia racemosa*. This specimen had no large laterals.

Few roots of *Sieversia* penetrate beyond depths of 5 feet and 6 inches. It sends out as many as 20–30 roots from a single inch of its thick rootstock. None of these roots are over 3–4 millimeters in diameter. They pursue a vertically downward course and branch profusely all the way to the tip, sending off laterals seldom over 3 inches long but branched to the fifth order. The roots are jet black. Eleven plants were examined on a northeast slope and an average root depth of 4 feet and 8.6 inches was determined.

### *Sidalcea oregana*

This mallow is confined to north hillsides and low ground. While much less abundant than *Geranium viscosissimum*, it is similar in habit in exposing a great number of large leaves. This plant may reach a height of over 3 feet. It blossoms later than *Geranium* but like it retains green foliage until frost.

Only two root-systems were examined. In both numerous strong laterals were thrown off within 4 inches of the surface. At 24 inches the tap broke up into three nearly equal parts, the largest and longest part reaching a depth of only 3 feet and 1 inch. The other plant reached a depth of 4 feet and 1 inch. *Sidalcea* roots cannot easily be confused with others for they send off small laterals in groups ranging from 3 to 8 in a group. This is most pronounced in the older parts of the roots. Often where a big lateral comes off one or more little ones originate with it. These groups of small laterals are usually less than 2 inches in length.

### *Hieracium scouleri (Fig. 17)*

The Hawkweed, with its densely hairy clusters of basal leaves, and its similarly leaden colored cauline leaves and stems reaches a height of about two feet. The rather small yellow flowers appear late in June and blossoming continues until August, even after the basal leaves have dried and turned brown. It is an important prairie species.

Twenty-six root-systems were examined. They gave an average depth of 5 feet and 4.3 inches. *Hieracium* sends out numerous roots,—as many as 50 from a single inch of its corymb—which in turn is from 8–12 inches long. None of these roots are over 3 millimeters in diameter. They pursue a nearly vertically downward course and throw off practically no laterals, except when they enter earthworm holes. Here, strong laterals equaling the main root in diameter, are thrown off and run parallel with it in the hole a foot or two or further. All give rise to abundant root hairs and it is seldom that these roots again enter the soil. The main root may branch very profusely or very little (in hard soil) at the tip. These light-cream-colored roots are very brittle but are easy to follow because of their latex. The acrid taste also is very characteristic and this character was sometimes used to distinguish *Hieracium* roots, especially near the tip where the latex is less abundant. The longest root reached a depth of 7 feet and 9 inches. Fifteen plants on a northeast slope gave an average depth of 5 feet and 2.8 inches; five on a southwest slope 5 feet and 3.4 inches; and six on a northwest slope 5 feet and 8.8 inches.

### *Potentilla blaschkeana*

This very common prairie plant occurs in all situations, but shows a decided preference for the more moist conditions. A few new leaves may appear in the fall, but the plant starts renewed growth early in April. It blossoms in late May and dries out during July or August, depending upon the environmental conditions.

The tufted stems are borne on a short, thick crown from which several (2-5) main roots originate. These average about 7 millimeters in diameter. They taper off gradually till at about two feet in depth they are often only 2 millimeters in diameter. Here they usually branch dichotomously, and again branching break up into numerous small roots—mere hairs—which have a strong tendency to grow in earthworm holes. These they follow for two feet, perhaps, before entering the soil again. In these holes they give off many threadlike branches which follow down the same hole branching profusely, and often never re-entering the soil. The roots are dark brown in color. They are unbranched or very poorly branched at the tip. Thirty root-systems were examined. Three of the longest roots penetrated to depths of 6 feet and 9 inches; 7 feet and 5 inches; and 7 feet and 5 inches respectively. The average depth was found to be 5 feet and 1.8 inches. Twelve plants on a northeast slope gave an average root depth of 4 feet and 11.2 inches, while 17 on a northwest slope reached an average depth of 5 feet and 4.3 inches.

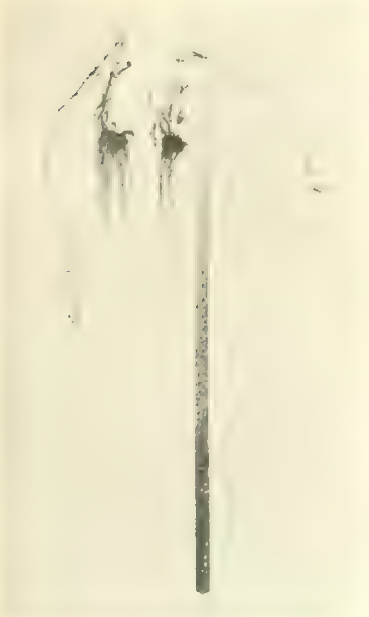

Fig. 17

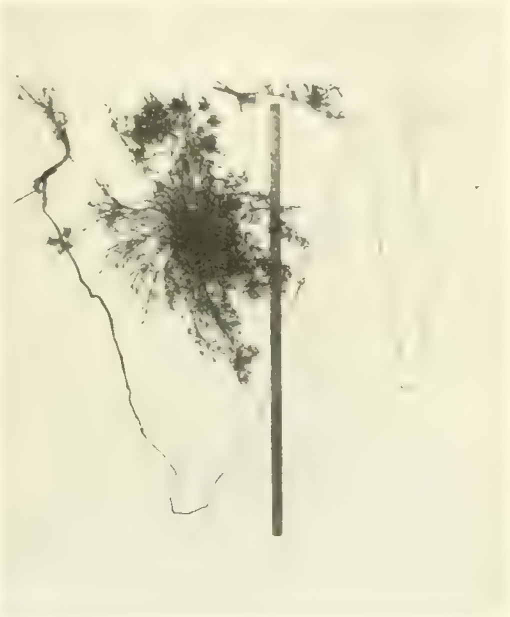

Fig. 18

Fig. 17. This shows the numerous roots sent out from the corymb of *Hieracium scouleri*. The total length of only one root is shown.

Fig. 18. *Eriogonum heracleoides* from the rim-rock. A single branch of the large mat is shown just above the meter stick. Note the adventitious roots. Only a small part of the complete root-system is shown in the figure.

### *Eriogonum heracleoides* (*Fig. 18*)

This plant seldom occurs except on the very driest ridges of high basaltic prairies, but is a very important ecological species upon the rim-rock and in the bunchgrass association. The great mats often cover an area of 2-3.5 square feet and the prostrate branches with their adventitious roots serve both to anchor the plant in place and lay hold upon the moisture of the superficial soil layers. It is a notable fact that the *Eriogonums* (including *E. compositum* and *E. niveum*) blossom and appear to thrive when most other plants of the rim-rock have long since dried out. This is explained in part by their extensive root-systems, of which the one shown in the figure will be described. A few others were excavated as checks.

The strong, woody, tap root 1 inch in diameter broke up at a depth of 6 inches into seven nearly equal laterals; only about one-fourth of the old tap root is shown in the figure. One of these laterals extended a distance of 13 feet and 6 inches as measured in a direct line from the plant, but had an actual length of 14 feet and 3.6 inches. It tapered off gradually, throwing off both large and small laterals which branched to the fifth order. Upon leaving the main tap it ran along in very shallow soil for 7 feet and 6 inches before turning down in the rock crevices, where it followed a very devious route dipping up and down more than a foot, and branching profusely to the tip.

Some examinations were also made of the roots of *Rosa nutkana*, and *Symphoricarpos racemosus*, both very common in nearly all prairie situations. They were found extending to depths of from 6 to over 8 feet. *Iris missouriensis* roots penetrated the soils of dry hillsides to 3 feet and 10 inches, and *Berberis repens* to a depth of over 10 feet. The orange-yellow roots of the latter, arising from the great system of horizontal stems on the rim-rock (where it often forms societies), resemble *Eriogonum heracleoides* in their abundant laterals and in the devious route they pursue in following the basaltic crevices.

Likewise, two species of *Lomatium*, *L. grayi* and *L. macrocarpum*, both abundant on thin soils, were examined. The long, fleshy, poorly branched taps are usually flattened, folded, and twisted as they crowd into the narrow crevices of the rock to depths of 3 to 5 feet or more. On the other hand, *Polygonum majus*, growing with *Poa* on thin stony soil, has a shallow but well developed root-system. The tap, seldom over 6.5 inches long (and usually less), sends off laterals profusely. In spite of the small leaf surface of this knot-grass, it has always been a puzzle to the writer how the plant could keep alive and even thrive and blossom abundantly from July to October upon the parched soils of the rim-rock.

## DISCUSSION AND CONCLUSIONS

The most obvious result of a consideration of these data is the fact that the response of the plant to these severe environmental conditions is met by well-developed and extensive root-systems. For just as the evaporating power of the air and the nature of the transpiring organs determine the water-requirements of plants, likewise the soil water and the nature of root-systems determine the water supply. It is interesting to note, however, that while the condition of light summer rainfall is quite unfavorable for shallow-rooted grasses, still three of the most important prairie grasses are shallow-rooted. Of these *Poa sandbergii* is the first to appear on the thin soils of the rim-rock and scab-land, where the underlying rock is little broken. In the prairie it is an important interstitial plant. It is only in the deep soils of the prairies that the shallow-rooted *Koeleria cristata* and *Festuca ovina ingrata* play their important rôle. The water-retaining capacity of the soils certainly favors these shallow-rooted species. On the other hand, the deep-rooted *Agropyron spicatum* early assumes importance as a crevice plant where sufficient cleaving of the rock has occurred. Indeed, from then on it becomes dominant in the bunchgrass association, where the soils of only a few inches depth overlie more or less decomposed basalt. In the prairie it is one of the facies, but under the new substratum conditions it partly abandons the bunch habit and may become more or less of a sod former. However, a discussion of the relation of root-systems to succession had best be considered at another time.

While the purpose of this study was not to arrive at a classification of root-systems, it is instructive to note that according to the types of root-systems as set forth by Cannon,[8] all the roots here described (with the possible exception of *Leptotaenia multifida*) fall under the generalized class. By a generalized root-system is meant one that has both the tap and the laterals well developed. They penetrate deeply and reach out widely. In contrast, the specialized root-system has either the tap root as the chief feature, or the laterals are placed near the surface, and especially well developed, as in cacti. The generalized type of root is much more plastic and consequently reacts to a wider range of conditions than does the specialized type.

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[8] Cannon, W. A. The Root Habits of Desert Plants, Carnegie Inst. Wash. Publ. 131. P. 87, 1911. See also Von Alten, Hermann, Wurzel-studien. Bot. Zeit. 67: 175–200, 1909.

In considering the question of the susceptibility of roots to modification through variation in the soil texture or its water content, as against the conservative inheritance tendencies, table 6 is instructive.

TABLE 6

*Average root depths of plants on different slopes*

| | S. W. SLOPE | N. E. SLOPE | N. W. SLOPE |
|---|---|---|---|
| | *inches* | *inches* | *inches* |
| *Lupinus ornatus* | 72.1 | 71.0 | 128.4 |
| *Lithospermum ruderale* | | 48.7 | 74.5 |
| *Potentilla blaschkeana* | | 59.2 | 64.3 |
| *Geranium viscosissimum* | | 56.1 | 72.2 |
| *Hoorebekia racemosa* | 64.0 | 63.4 | 68.2 |
| *Hieracium scouleri* | 62.8 | 63.4 | 66.8 |
| *Helianthella douglasii* | 52.0 | 55.6 | 55.1 |
| *Balsamorhiza sagittata* | 61.5 | | 69.8 |
| *Leptotaenia multifida* | | 54.7 | 47.3 |
| *Agropyron spicatum* | | 49.6 | 38.6 |

It appears that the root lengths on northeast and southwest slopes are about the same and that the marked environmental differences play little part in determining root depth. However, the writer is of the opinion that the hard soil on dry southwest slopes is a limiting factor to root growth. When we note the greater root development on the northwest slope, which, as has already been pointed out, combines a porous moist soil with rather extreme xerophytic above-ground conditions, this conclusion would seem to be warranted, although the evidence of *Leptotaenia* and *Agropyron* is to the contrary. But more data, both experimental and from field observations, are needed in this and other regions before this question can be answered. The illogical neglect of most ecologists in not working in this interesting field is to be deplored. However, we must not overlook the fact that the real solution of the problem of adaptation to environment will be solved only when the extent and character of both absorbing and transpiring parts of plants are studied and correlated. The writer has under way an investigation of the ecological anatomy of the leaves of the plants mentioned in this paper, together with the extent of the transpiring surface.

Cannon (*loc.cit.*) points out that for desert plants having generalized root-systems it is probable that the penetration of the roots, the character of the soil permitting, is equal to the penetration of rains; also that "the generalized roots are often extremely variable, ranging from a pronounced tap root to a marked development of laterals, dependent upon soil characters and water relations." No such marked changes as these were discovered, although since the variation in the branching habit is a matter of degree rather than kind, it would be difficult to express the differences in exact terms if indeed these differences had been noticeable. However, the roots of several species showed a marked increase in their output of branches upon leaving the compact soil and entering earthworm burrows. In practically all cases the root tips under such conditions were alive and at least well covered with root hairs, while in the more compacted soils of dry slopes especially, the root tips were often dead and decayed. The cause of these differences is yet to be determined. The differences may be due to the mechanical resistance offered by the soils, or to changed conditions of aeration, or perhaps to both factors acting together.

These findings of great root depths, correlated with deep soil moisture, bear out Cannon's suggestion of the probability that the longest or the most deeply penetrating roots are found, not in deserts, but where there is considerable rainfall, and where the penetration of rain is considerable and the water table relatively deep. It may be noted here, by way of comparison, that *Andropogon scoparius* at Manhattan, Kansas, penetrates the soil to

6 or 8 feet,[9] while Ten Eyck has shown that at the same station *Andropogon furcatus* reaches depths of 4.5–6.5 feet.[10] Likewise, Shantz[11] in his extensive studies on the Great Plains, has shown that the Prairie grass formation (characterized by the deep-rooted *Andropogon scoparius*, *A. halli*, *Psoralea tenuiflora*, *Redfieldia flexuosa* and others) is limited in its western extension by insufficient (deep) water supply, and is replaced by the shallow-rooted short grass formation.

The roots studied are remarkable for their individuality. The roots of each species, because of peculiarities of form, of branching habit, of position in the soil, of texture, color, odor or taste, can easily be distinguished, and these distinguishing characters have often proved useful in ecological work.

A knowledge of the distribution and extent of root-systems helps us to more coreectly interpret the present structure of vegetation as well as to analyze the causes which have led up to and are constantly active in modifying these conditions.

In concluding, I wish to acknowledge my deep indebtedness to my onetime student, Mr. Walter L. C. Muenscher, whose keen interest in the work made him my almost constant companion in the course of this study.

[9] Georgeson, C. C. and Payne, J. E., Bul. 75 Kans. Agric. Col., 1897.

[10] Ten Eyck, A. M., Bul. 127 Kans. Agric. Col., 1904.

[11] Shantz, H. L., Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in The Great Plains Area. Bul. 201 Bureau of Plant Industry, 1911.

# BOOKS AND CURRENT LITERATURE

Western Wild Flowers.—Many persons are attracted by the wild flowers which they encounter in their excursions, but do not desire in the least to take up the study of botany. They are, indeed, repelled by the manuals which lock up a knowledge of the floras of their several regions, and are unwilling to attempt to master the keys provided to open it to them. For the convenience of these flower-lovers many guides of a less technical character have been provided, especially in recent years, in which the study of nature has received so great an impulse. They vary in value as in scope, and botanists should be glad to find one they can recommend to those who inquire for something they can understand. Such a book is Miss Armstrong's Western Wild Flowers, whose botanical correctness is guaranteed by the collaboration of Professor Thornber.[1] The numerous illustrations, in black and white and in color, will be of great assistance to those for whom the book is designed. Its field includes the seven western states from Washington and Idaho to Utah and Arizona, so that the large number of plants described are of necessity but a small part of the flora of that vast and varied region. But the purpose seems to have been to include plants which, by the beauty or unusual structure of their flowers, as well as by their occurrence in places readily visited, are most likely to attract the attention of those who will use the book, and at the same time to present representatives of the various families found in the region covered. Most books of this kind omit all the difficult genera, but in this one only the grasses and the sedges are unincluded. On the whole the selection is judicious, although one is surprised at the absence of some species and at the inclusion of others; but this would certainly be the case whoever made the choice.—S. B. Parish.

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[1] Armstrong, Margaret, Field Book of Western Wild Flowers. In collaboration with J. J. Thornber, A.M. Figs. 500, pls. in color 48. New York, G. P. Putnam's Sons, 1915 ($2.00).

## NOTES AND COMMENT

The recent mention in these pages of the papers on plant distribution which were read at the San Francisco meeting of the American Association has caused one of our correspondents to send us the titles of papers on the same subject which were read in two symposiums held twenty-five and fifteen years ago respectively. The first of these was at the Indianapolis meeting of the American Association in 1890, the second at the New York meeting in 1900. The titles of these contributions are worthy of republication at the present time, as they afford an index of the major interests in American plant geography during a period of ten years or more.

Papers read at the Indianapolis Meeting:

Sereno Watson. The relation of the Mexican flora to that of the United States.
John M. Coulter. Geographical distribution of North American Umbelliferae.
Lucien M. Underwood. The distribution of Hepaticae of North America.
Byron D. Halsted. The migration of weeds.
W. J. Beal. Geographical distribution of the grasses of North America.
John M. Coulter. Geographical distribution of North American Cornaceae.
N. L. Britton. On the general geographical distribution of North American plants.

Papers read at the New York Meeting:

B. L. Robinson. Distribution of the Spermatophytes in New England.
J. K. Small. Distribution of the Spermatophyta in the southeastern United States.
Thomas H. Kearney. Notes on the Lower Austral element in the flora of the southern Appalachian region.
H. C. Cowles. Physiographic ecology of northern Michigan.
Roscoe Pound. Vegetative elements of the sandhill region.
P. A. Rydberg. Composition of the Rocky Mountain flora.
C. V. Piper. Flora of the Columbian lavas.
G. V. Nash. Distribution of the grasses of North America.
W. L. Bray. Relationship between the North and South American floras.
J. N. Rose. Floral zones of Mexico.
N. L. Britton. Origin of the flora of North America.

The majority of the participants in these symposiums are best known through their work in systematic botany, a circumstance which calls attention to the fact that during the past decade there have been very few contributions to plant geography from the systematic botanists of this country. This may be due to the absorbing task which has busied all taxonomic workers in the description of fresh material from little-known regions, or in altering the names of plants from well-known regions, or it may be due to the inherent difficulty of arriving at fresh generalizations in phytogeographic work. Such recent papers as those of Dr. N. L. Britton on the vegetation of Mona Island and of Dr. P. A. Rydberg on the alpine flora of the Rocky Mountains show that phytogeography still makes a strong appeal to the systematist whenever he contemplates the larger features of his work. It is to the systematist that we must look for our soundest work in floristic plant geography, and it is greatly to be hoped that he will not neglect this opportunity for the widening of his work.

Miss Josephine E. Tilden, of the University of Minnesota, announces that she is now prepared to distribute 6000 cards of her *Index Algarum Universalis*. This *Index* furnishes a complete bibliography of literature on algae, under the four headings: authors, genera and species, geographical areas, and general subjects. It is Miss Tilden's aim to bring the *Index* up to date during 1916, and thereafter to keep it abreast of the current literature.

We wish to remind our readers of the two prizes of $50 and $15 which are offered by this journal for the best papers on the water relations of plants. All papers submitted in competition should be in the hands of the Editor by December 1, 1915. Fuller information regarding the contest may be found in the April issue.

# AN INVESTIGATION OF THE CAUSES OF AUTONOMIC MOVEMENTS IN SUCCULENT PLANTS

EDITH BELLAMY SHREVE
*Tucson, Arizona*

## I.

The study of autonomic movements in plants has attracted the attention of many notable workers throughout several decades, but as yet very few have been able to attain an approach to the goal of ultimate causation. Various kinds of movements have received attention and their causes have been ascribed to such things as changes in geotropic irritability, differential growth, changes in the turgidity of special organs, caused in turn by changes in permeability of protoplasm, to temperature, to light, etc.; but the causes of the changes in geotropic irritability (whatever the term may mean), of differential growth, of permeability changes, or the mechanism by which light and temperature act, have not been found. There have come to the attention of the writer no papers dealing with autonomic movements in succulents and it seemed probable that a study of movements in this class of plants might bring to light new facts which would in the end aid in the discovery of the ultimate physicochemical causes for at least one class of movements.

In the following report new facts regarding movements do appear and their causes are traced to a physical source but this source is, alas, still far from the ultimate cause. This paper will, however, be followed at an early date by another which will contain the results of a further research into the mechanism of the physical source mentioned above. In the present paper the usual terms "irritability," "internal stimulus," "response" have been avoided because in the opinion of the writer they mere-

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ly mask the true condition of the state of knowledge of cause and effect.

The investigations set forth in the following pages were carried on at the Desert Laboratory at Tucson, Arizona. The writer wishes to express, here her gratitude to Dr. D. T. MacDougal not only for the use of the facilities of the laboratory but also for helpful suggestions concerning the work.

Autonomic movements of an etiolated joint of a platyopuntia were described by MacDougal in 1910,[1] and in 1912[2] he observed an attenuated plantlet of *Opuntia versicolor*, that within a period of three days showed movement in a vertical direction through an arc of 180° and in a horizontal direction through an arc of 2 to 10°. During the last few years the writer has at various times observed that joints or limbs of *Opuntia versicolor*, *O. fusicaulis*, *O. Toumeyi*, and *Carnegiea gigantea* have changed their positions from time to time. The work presented here was undertaken with a view to finding the exact nature of these movements and the cause of them. *Opuntia versicolor* was chosen as the subject of the main part of the investigation on account of the convenience of procuring large numbers of individuals. This is a much-branched, semi-arborescent cactus, made up of joints 1 to 4 cm. in diameter and 5 to 30 cm. in length. The younger plants, 1 to 10 years old, have joints in all respects like those of the same age on older plants.

The plants used as material for the observations and experiments retain the same designation by number or by letter throughout the paper. They fall into three classes: (1) Nos. 1, 2, and 14, which were raised from seed in a green-house and were 4 years old when used; their joints were more attenuated than is usual with plants grown in the open but they were plump and turgid. (2) Nos. 3 to 34 inclusive, excepting 14, which were taken from the ground three months to a year before they were used and were planted in pots. (3) Nos. A to G which were growing in the open and left undisturbed.

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[1] MacDougal, D. T., and Cannon, W. A., The conditions of parasitism in plants. Carnegie Inst. Wash., 1910.

[2] From unpublished notes kindly furnished the writer by Dr. MacDougal.

Casual observations made it seem probable that the various positions assumed by the joints were related to the degree of turgidity of the tissues. Hence measurements were made on plants in wet and in dry soil. In potted plants the soil water-content could, of course, be controlled. The measurements on plants growing in the open were made at various times of the year when the interval between rains was known.

The first set of observations was made on both potted plants and on plants growing out of doors. The differences in posi-

TABLE 1

*The relation of movements of joints of Opuntia to the water-content of the soil.*

*Plant No. 2*

| | A | B | C | NOTES |
|---|---|---|---|---|
| Oct. 2 to 17 | −19.1 | −3.5 | −8.3 | No water given between the dates. Pot open. |
| Oct. 17 to 22 | +14.6 | +3.4 | +7.5 | Watered every two days after Oct. 17 |

*Plant No. 3*

| | A | B | | |
|---|---|---|---|---|
| May 27 to Aug 7 | −5.2 | −1.0 | | No water given between dates. Pot sealed. |
| Aug. 7 to 11 | +5.4 | +0.6 | | Watered on Aug. 7 |

*Plants Nos. 7 and 8*

| | NO. 7A | NO. 8 | | |
|---|---|---|---|---|
| Oct. 22 to Jan. 21 | −20.8 | −24.0 | | No water given between dates. Pots sealed. |
| Jan. 21 to Mar 20 | +20.3 | +23.7 | | Watered frequently after Jan. 21. |

*Plants A and C*

| | A1 | A2 | A3 | C1 | |
|---|---|---|---|---|---|
| Oct. 22 to Dec 2 | −5.5 | −4.5 | −2.5 | −13.0 | No rain between dates |
| Dec. 2 to Mar. 20 | +5.5 | +4.7 | +3.7 | +11.0 | Many showers after Jan. 21 |

tion which took place during the intervals between measurements are given, in centimeters, in table 1, the plus sign being used to denote an upward movement and the minus, a downward one. The general appearance of the plants under the several conditions is indicated by the diagrams in figure 1. These show only the extreme positions assumed in wet and in dry soil. The downward movement took place gradually, occupying weeks or months, while the upward movement was rapid after rain or irrigation and occupied only a few days.

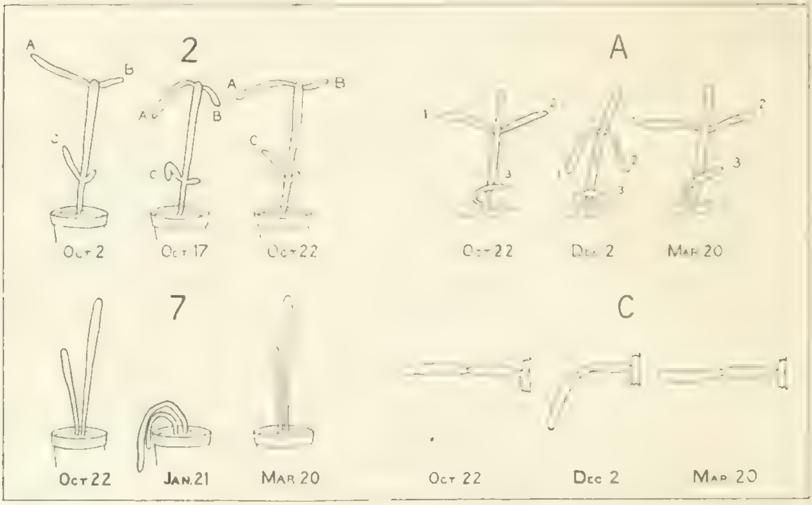

Fig. 1. Diagrams to illustrate the relations of movements of *Opuntia versicolor* to the water-content of the soil. For details see table 1.

The second set of observations was made by means of measurements and by securing series of photographs. Negatives were made of five adult plants, growing in the open, at successive seasonal periods of wet, dry, and wet soil, the camera being accurately placed in the same position each time. All five of the plants showed similar behavior. In figure 2 appear views of the smallest plant of the series.

Both of the above sets of observations show that when the positions are noted at the same time each day, they change with the amount of water in the soil, a low position being assumed

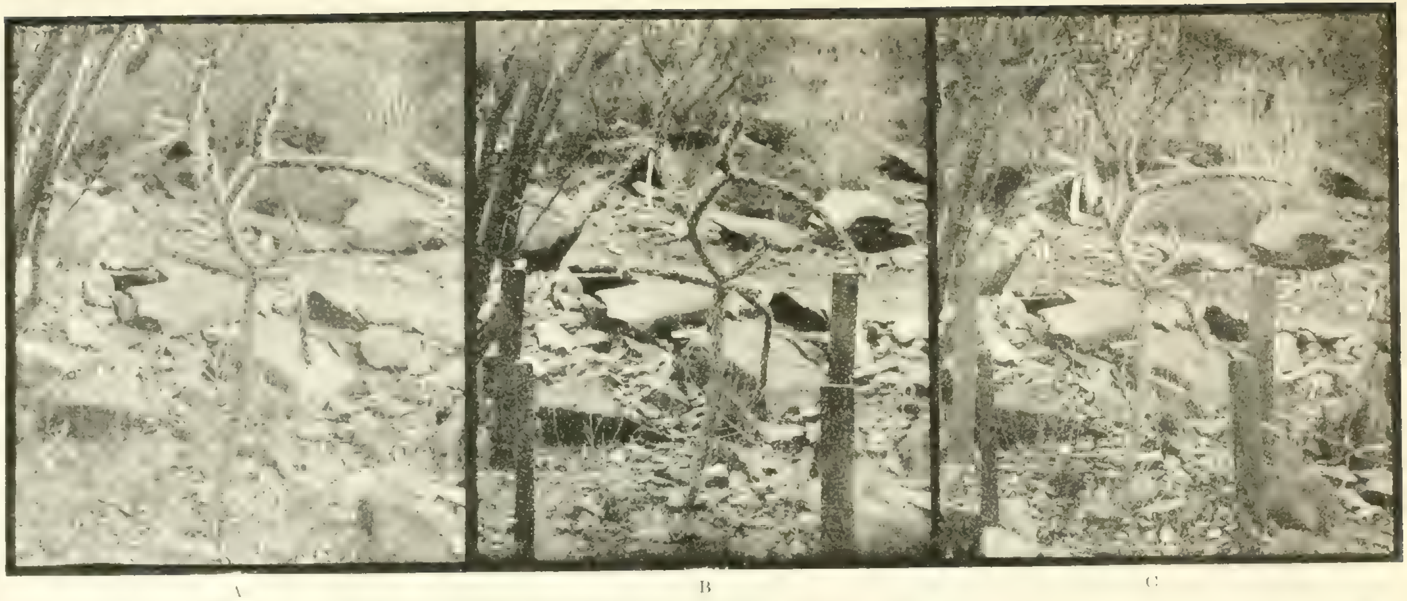

Fig. 2. Positions of branches of a plant of *Opuntia versicolor* at three seasons of the southern Arizona climate, showing the relation of movements to the water-content of the soil. A. October 22, 1912, after the close of the summer rains. Water-content of soil high. B. December 1, 1913, in the midst of the autumn dry period. Water-content of soil very low. C. March 20, 1913, at the end of the winter rains. Water-content of soil high.

during progressive desiccation and a higher one after subsequent rain or irrigation.

When the plants are in dry soil their tissues are shrunken and have distinct ridges and furrows around the tubercles. After rain or irrigation, as well as before any desiccation has occurred, the joints are plump and have many signs of being more turgid than when in the desiccated condition. A test of the water-content of joints one year old gave 18 grams of water per gram of dry weight for joints in the high position and 10 grams for the low one. These values were obtained by heating severed joints to constant weight at 100°C. Ten separate determinations were made and the results averaged. The individual variations were sometimes as great as 20%.

It is evident that the movements thus far considered are due to changes in turgidity. Measurements were also made on *Carnegiea gigantea*, and on *Opuntia fusicaulis*, which show that they have similar movements. Frequently joints continue the growth of their vascular tissue while they are in the low positions and when the rains come they are too stiff to return to their former erect positions. Thus the curious final forms of the cacti are determined by the amount of drought the plants experience during the last stages of the secondary thickening of the joints and not by any peculiarity of the growing points.

When soil conditions remain fairly constant no observable change of position takes place, provided the measurements are made at the same time each day. However, when measurements are made at 2 to 12 hour intervals another phenomenon appears which may be said to be superposed upon the nearly constant position in soil of unchanging water-content, as well as upon the general downward or upward motion in soil of decreasing or increasing water-content. This new movement takes place within each 24 hours and may be described briefly, as consisting of a downward movement at night and an upward one during the day. Certain exceptions to this general rule occur and will be considered. The character and amount of this motion, together with a general description of the accompanying environmental conditions, will be seen from the following experiments.

Preliminary experiments, which will not be recorded here, gave some evidence that the short period movements are controlled by temperature, light, the water-content of soil and of tissues, both at the time of the experiment and previously, and possibly also by the evaporative power of the air. Consequently, movements have been measured under various environmental conditions and a record kept of these conditions. In experiments 1–6, the normal range of day and night temperatures and light have been used with a variation in the water-content of soil and tissues. In experiment 7, the light and temperature changes are still the normal ones but the plants are exposed to different wind velocities and hence to different evaporative intensities. Experiment 8 covers various conditions of light and temperature changes with the water-content of soil and tissues remaining as nearly constant as possible.

TABLE 2

EXPERIMENT 1. *Movements of three branches of Plant No. 4*

| | | A | B | C |
|---|---|---|---|---|
| Mar. 8 | 7.30 a.m. to 7.30 p.m. | +4.0 | | +4.3 |
| Mar. 9 | 7.30 p.m. to 7.30 a.m. | −0.4 | −1.1 | −3.7 |
| | 7.30 a.m. to 7.00 p.m. | +2.4 | +0.6 | +4.5 |

TABLE 3

EXPERIMENT 2. *Movements of Plant No. 8*

| | | |
|---|---|---|
| Mar. 11 | 9 a.m. to 10 a.m. | +0.1 |
| | 10 a.m. to 11 a.m. | +0.1 |
| | 11 a.m. to 12 noon | +0.6 |
| | 12 noon to 4 p.m. | +0.7 |
| | 4 p.m. to 7 p.m. | 0.0 |
| Mar. 12 | 7 p.m. to 7 a.m. | −0.9 |
| | 7 a.m. to 10 a.m. | +0.5 |
| | 10 a.m. to 12 noon | +0.9 |
| | 12 noon to 4 p.m. | +2.9 |

TABLE 4

EXPERIMENT 3. *Movements of Plant No. 1, branches A, B and C*

| TIME | | A | B | C |
|---|---|---|---|---|
| Mar. 10 | 7 a.m. to 12 noon | +0.6 | +0.3 | +1.4 |
| | 12 noon to 4 p.m. | +0.2 | +0.2 | +0.4 |
| | 4 p.m. to 7 p.m. | −0.5 | −0.5 | −0.8 |
| | 7 p.m. to | | | |
| Mar. 11 | 7 a.m. | −1.5 | −1.3 | −1.1 |
| | 7 a.m. to 8 a.m. | +0.4 | +0.4 | +0.3 |
| | 8 a.m. to 9 a.m. | +0.3 | +0.5 | 0.0 |
| | 9 a.m. to 11 a.m. | +0.3 | 0.0 | +0.6 |
| | 11 a.m. to 2 p.m. | 0.0 | 0.0 | +0.5 |
| | 2 p.m. to 4 p.m. | 0.0 | 0.0 | 0.0 |
| | 4 p.m. to 7 p.m. | +0.3 | +0.2 | +0.3 |
| | 7 p.m. to | | | |
| Mar. 12 | 7 a.m. | −1.2 | −1.2 | −2.4 |
| | 7 a.m. to 10 a.m. | 0.0 | 0.0 | −0.5 |
| | 10 a.m. to 11 a.m. | 0.0 | 0.0 | +0.3 |
| | 11 a.m. to 12 noon | 0.0 | 0.0 | +0.2 |
| | 12 noon to 4 p.m. | 0.0 | −0.6 | 0.0 |
| | 4 p.m. to 7 p.m. | 0.0 | | 0.0 |
| | 7 p.m. to | | | |
| Mar. 13 | 7 a.m. | −0.8 | −0.7 | −2.1 |

TABLE 5

EXPERIMENT 4. *Movements of Plants No. 11 and No. 12*

| PLANT NO. 11 | | | PLANT NO. 12 | | |
|---|---|---|---|---|---|
| Mar. 9 | 7 a.m. to 7 p.m. | +1.0 | Mar. 11 | 7 p.m. to | |
| | 7 p.m. to | | Mar. 12 | 7 a.m. | −0.2 |
| Mar. 10 | 7 a.m. | −0.8 | | 7 a.m. to 10 a.m. | +0.2 |
| | 7 a.m. to 12 m | +0.3 | | 10 a.m. to 12 noon | +0.5 |
| | 12 noon to 4 p.m. | +0.2 | | 12 noon to 4 p.m. | +0.3 |
| | 4 p.m. to 7 p.m. | 0.0 | | 4 p.m. to 7 p.m. | 0.0 |
| | 7 p.m. to | | | 7 p.m. to | |
| Mar. 11 | 7 a.m. | −0.7 | Mar. 13 | 7 a.m. | −0.8 |
| | 7 a.m. to 8 a.m. | +0.2 | | 7 a.m. to 10 a.m. | +0.5 |
| | 8 a.m. to 9 a.m. | 0.0 | | 10 a.m. to 12 noon | +0.4 |
| | 9 a.m. to 11 a.m. | +0.2 | | 12 noon to | |
| | 11 a.m. to 2 p.m. | 0.0 | Mar. 14 | 7 a.m. | −0.4 |
| | 2 p.m. to 4 p.m. | +0.3 | | | |
| | 4 p.m. to 7 p.m. | −0.2 | | | |

Thermograph records were taken, and have been presented in the accompanying figures. An arbitrary and very crude method for indicating changing light conditions has been adopted. A convenient distance was chosen as the height to represent the light conditions in the open when the sky is clear and the sunlight falls directly on the plants; one-half of this amount represents complete cloudiness or the shade within the laboratory. No attempt was made to indicate anything beyond the grossest changes in light intensity, such as are caused by partial or intermittent cloudiness. A clear day is represented by a straight line from sunrise to sunset regardless of the fact that the intensity changes from hour to hour.

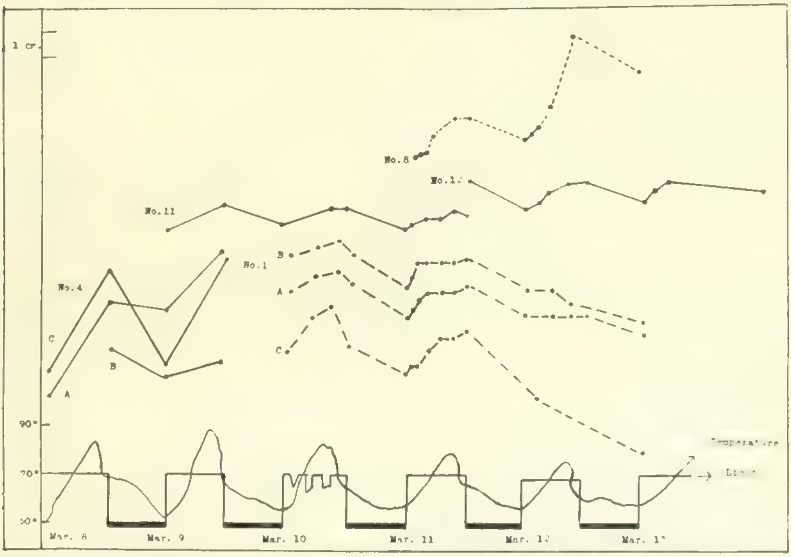

Fig. 3. Movements of *Opuntia versicolor* under three conditions of water relations. See tables 2–5. Plants Nos. 4, 11, and 12 (solid line) are of normal turgidity throughout the experiment. Soil continuously wet. Plant No. 1 (broken line) is of normal turgidity at the start of the experiment. Soil is drying out. Plant No. 8 (dotted line) is recovering from a previous short desiccation period. Soil continuously wet.

EXPERIMENT 1. March 8–9, 1911.

*Object:* The measurement of day and of night movements of a plant under green-house conditions. Water-content of soil high.

*Material:* Plant No. 4, an individual with two branches grown in the open and three in the green-house. The measurements were made on the branches which grew in the green-house. The soil has been kept continuously moist for over a month.

*Results:* The data are recorded in table 2 and given in graphic form in figure 3.

Experiment 2. March 12–13, 1914.

*Object:* The measurement of movements at intervals during the day, with a single measurement for the night, uñder green-house conditions and with the plant recovering from drought in wet soil.

*Material:* Plant No. 8, an unbranched small individual which made its growth in the open. The previous history of this plant is shown in figure 1. At the time of the experiment it was in position 3. The soil had been kept continuously wet since the watering on January 21. At 7 p.m. on March 12 a small amount of water was given in order to prevent even a slight drying lut during the night. A small "w" on the graphs always indicates the time at which water was added.

*Results:* Data are given in table 3 and figure 3.

Experiment 3. March 10–12, 1914.

*Object:* The measurement of changes in position at frequent intervals, under green-house conditions and in soil which is gradually drying out.

*Material:* Plant No. 3, a three year old, which had spent its entire life in the green-house. It was 50 cm. high and bore three branches. All three branches were in positions intermediate between 1 and 2 in figure 1.

*Results:* The data are given in table 4 and figure 3.

Experiment 4. March 9–11, 1914.

*Object:* The measurement of changes in position at frequent intervals under green-house conditions and in wet soil, using plants which have never suffered from drought.

*Material:* Plants No. 11 and 12. Both were small individuals about 15 cm. high and were in erect positions. They had made their entire growth in the green-house.

*Results:* Data appear in table 5 and figure 3.

Experiment 5.

*Object:* The duplication of experiments 1–4.

*Material:* Plants Nos. 1, 2, 4, and 5.

*Method:* Experiments 1–4 were repeated under as nearly identical conditions as could be obtained on different days.

*Results:* The data were in all respects similar to those in the previous experiments; so that the graphs of these experiments would, if slightly smoothed, represent the graphs for the movements in experiment 5.

Experiment 6.

*Object:* The measurement of movements for day and night under extremely desiccated conditions of soil and plant, and later of movements of the same plants after irrigation.

*Material:* Plants Nos. 3, 4, 7, and 8. All had received no water for two months and the branches were in the lowest possible positions.

*Results:* Measurements extending over two weeks showed no movement either during the day or at night for plants under conditions of extreme desiccation. Measurements during two days and nights immediately after irrigation showed a continuous rise for both day and night, but a faster rate for the day than for the night. Plant No. 4 was kept in constant darkness after irrigation and continued to rise during the two days and nights. Its rate was slower than that of the others, but the rates varied so much from plant to plant and from branch to branch that it was impossible to tell what the rate of No. 4 might have been if it had not been kept in darkness.

TABLE 6

EXPERIMENT 7. *Movements under different conditions of evaporating power of the air*

| | PLANTS | | | | | NOTES |
|---|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 8 | No. 15 | No. 16 | |
| Sept. 4 | | | | | | |
| 10 a.m. | +4.0 | +3.1 | +0.8 | +0.5 | +0.7 | In greenhouse. Sun bright. Evaporating power of air low. |
| 2 p.m. | +3.5 | +2.0 | +0.3 | +0.1 | +0.2 | |
| Sept. 5 | | | | | | |
| 10 a.m. | −3.2 | −1.7 | −0.4 | +0.3 | +0.4 | In the open. Sun bright, wind velocity very high. |
| 2 p.m. | 0.0 | 0.0 | −0.5 | 0.0 | +0.1 | Evaporation extremely high. |
| Sept. 6 | | | | | | |
| 10 a.m. | −1.0 | −0.2 | 0.0 | +0.4 | +0.5 | In the open. Sun bright. Wind velocity medium. Evaporating power of the air high. |
| 2 p.m. | −0.5 | −0.3 | 0.0 | +0.4 | +0.3 | |
| 3 p.m. | 0.0 | −0.3 | −0.2 | +0.1 | 0.0 | |
| 4 p.m. | | | | | | |
| 6 p.m. | −1.5 | 0.0 | 0.0 | −0.2 | 0.0 | |

EXPERIMENT 7.

*Object:* Measurement of movements under conditions of the high evaporation existing in the open in the sun, with the tissues of the plant turgid and the soil water content high.

*Material:* Plants Nos. 1, 2, 8, 15, and 16. Plants 1 and 2 had spent their entire life in the green-house, the others in the open.

*Method:* All plants were measured at four-hour intervals, on the first day in the green-house, on the second day in the open, under the influence of bright sun and a high wind. On the third day the plants were again placed in the open, but on this day the velocity of the wind was not so high. The plants were placed in the green-house at night.

*Results:* The movements are shown in table 6. Two of the three plants which had grown in the open, Nos. 15, and 16, moved upward both in the green-house and in the open. The two plants which were grown in the green-house moved upward under green-house conditions but downward when placed under the conditions of higher evaporation in the open. Plant No. 8, which had grown in the open, behaved in the same manner as the green-house grown plants.

Experiments 1–7 show that young turgid joints which have not recently suffered from drought, when placed under conditions of average evaporative intensity and subjected to the normal day to night changes in light intensity and air temperature, show short periodic movements, consisting of a rise during the daylight and a drop during darkness hours. The rise is greatest in the forenoon, frequently ceasing, or even being replaced by a drop, after four o'clock. In other words, during the time of greatest evaporative intensity of the day the plant is erecting itself and during the time of lowest evaporation it is drooping. This characteristic movement is influenced by the amount of water in the soil and may be stopped or reversed by allowing the plant to become desiccated and subsequently irrigating. A very high evaporative intensity may also give a downward movement during the day to a joint which has grown in the greenhouse and sometimes to a very young joint which has made its

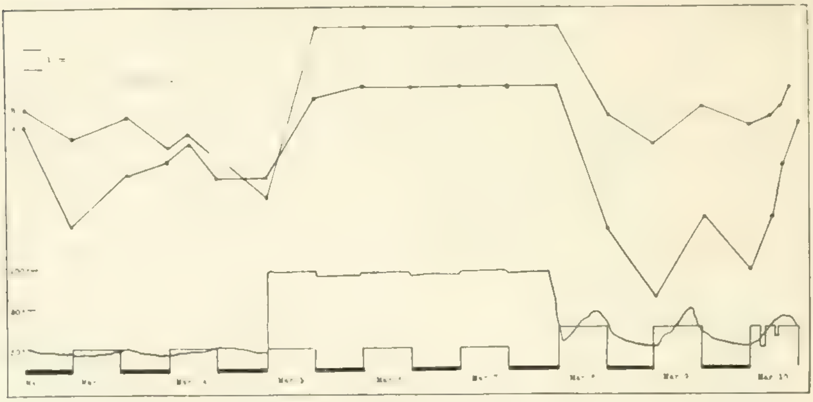

Fig. 4. Movements of *Opuntia*. March 2–4, low temperature with an alternation of diffuse light and darkness. March 5–7, high temperature with an alternation of diffuse light and darkness. March 8–10, normal day to night changes in temperature and light. Two lowest graphs indicate temperature and light conditions. See experiment 8.

growth in the open. The next experiment records the influence of other combinations of environmental factors upon the movement.

EXPERIMENT 8.

*Object:* An investigation of the influence of light and temperature upon the day and night movements, by means of their measurement under conditions of (1) constant high temperature with an alternation, at twelve hour intervals, of diffuse light and darkness; (2) constant high temperature with an alternation of sunlight and darkness; (3) constant low temperature with an alternation of diffuse light and darkness; (4) constant low temperature and constant darkness; (5) constant darkness with an alternation every twelve hours, of high and low temperatures.

For the high temperatures 90° to 100° F. were selected and for the low ones 55° to 60° F., the idea being that these represented the average maximum and minimum to which plants are normally subjected. Thus any metabolic changes which might influence the movements would still appear.[3]

*Material:* Plants Nos. 1, 2, 4, and 7. Nos. 1 and 2 were green-house raised plants; Nos. 4 and 7 were from the open.

*Method:* The constant high temperatures were obtained by placing the potted plants within glass cages (about 15 cubic feet capacity) which were fitted with electric heaters and automatic controls. The temperature between the top and bottom of the cages varied from 1° to 1.5° F., while at a given level the variation was no greater than 0.2° F. The thermograph was placed at the mean level of the aerial parts of the plants. For the constant low temperature, a vault beneath the laboratory was used. No means was at hand for obtaining a constant low temperature in sun-light. Unless statements are made to the contrary, the plants used were at nearly maximum turgidity and were in wet soil.

*Results:* The movements are recorded in the form of graphs in figures 4–6. Light and temperature changes are indicated in the same manner as in previous experiments.

When the behavior of the plants is examined from the graphs the following facts appear. The characteristic upward and downward movements for day and night cease entirely under conditions of (1) constant high temperature with an alternation every twelve hours of darkness and diffuse light; (2) constant high temperature with an alternation of darkness and sunlight; (3) nearly constant low temperature with an alternation of darkness and diffuse light; (4) constant low temperature and constant darkness.

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[3] It was thought when these conditions were planned that acidity changes within the plant could be predicted from the work of H. M. Richards (Acidity and gas interchange in cacti. Carnegie Inst. Pub. 209), and G. Krause (Die Wasserverteilung in der Pflanze. Abhand. d. Natrfor. Ges. Halle, **16**, 143). But later, when acidity determination were made on the material under these conditions, the results showed that further work must be done on acidity relations before such predictions can be made with any degree of accuracy.

In the case of the continued darkness with an alternation of high and low temperatures, the first twenty-four hours shows the characteristic movements but the second period of low temperature fails to show the downward movement and after this, one plant continues a general downward movement, while the other moves upward during exposure to high temperature and downward under the influence of low temperature.

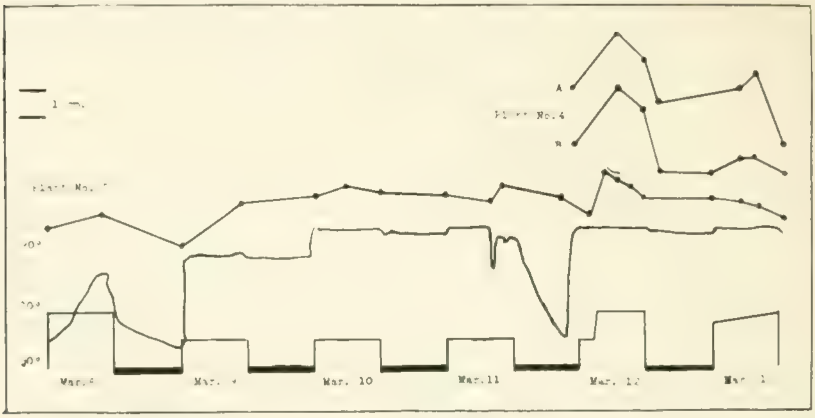

Fig. 5. Movements of *Opuntia*. March 8, normal day to night changes in temperature and light. March 9–11, high temperature with an alternation of diffuse light and darkness. March 12–13, high temperature with an alternation of normal day to night changes in light. Two lowest graphs indicate temperature and light conditions. See experiment 8.

All of the plants resumed their characteristic movements when they were again placed under normal conditions, but not until one period of low temperature and darkness had been experienced.

Thus it appears that an interruption of the normal day to night changes in temperature and light intensity breaks the sequence of day to night movements. It is evident that both light intensity and temperature influence the movements, but a given light intensity or temperature or any combination of the two will not produce a given movement unless they have been preceded by the proper combination of light and temperature. The duration of these conditions is also of importance. For example, an upward movement takes place under conditions of strong light intensity and high temperature, provided the plant has been subjected to a low temperature and darkness for a period immediately preceding. Further, a downward movement at low temperature and with weak light intensity takes place only when these conditions follow high temperature and strong light. These periods need not be as long as twelve hours, as may be seen from the graph on March 11 and 12, when the heating unit failed to work and is so recorded by the thermograph trace.

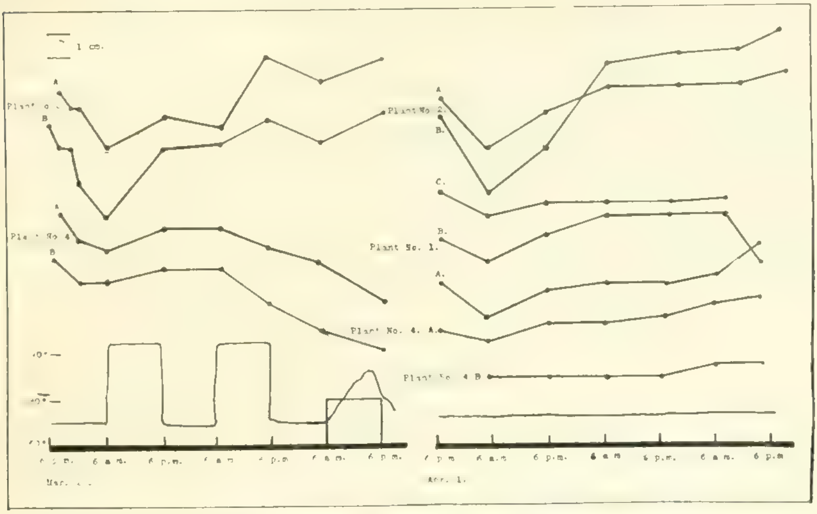

Fig. 6. Movements of *Opuntia* March 20–24, constant darkness with an alternation of low and high temperatures at twelve hour intervals, followed by one day of normal conditions. April 1–4, constant darkness and constant low temperature. Two lowest graphs indicate temperature and light conditions. See experiment 8.

The facts brought out in the last paragraph show that the influence of temperature and light intensity on the movements cannot be a direct one. The temperature and light must exert an influence on some other processes which in turn influence the movements. Quite possibly the movements are either caused by, or controlled by metabolic changes which in their turn are controlled by light and temperature. It is also possible that there are still other intermediate factors. One that forces itself upon the attention is the turgor changes in the tissues. At first it seems absurd that these plant movements could be due to such changes, since the time of lowest turgor would have to come at night, a time when all plants so far as known from previous work, have their greatest turgor. However, it must be noted that all of the changes in environment which have been considered have unavoidably included changes in the evaporative intensity of the air, and therefore in the amount of water lost by transpiration. Always though, the downward movement occurred when the plant was "logically" losing the least amount of water and an upward one when transpiration was greatest; so that it seems impossible that the plant could have the greatest turgor when the joints are moving upward.

*To be continued*

# A USEFUL DRAWING CAMERA

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While studying recently in the Botanical Institute in Leipzig, I had occasion to follow closely the course of the geotropic reaction and subsequent autotropic flattening of primary and secondary roots. To record such reactions by means of occasional free hand drawings is highly unsatisfactory because of the unavoidable inaccuracy of such drawings.

The method employed by Simon (Untersuchung über den autotropischen Ausgleich geotropischen und mechanischen Krümmungen der Wurzeln, Jahrb. der wiss. Bot., Bd. 51, S. 81) leaves much to be desired. He placed the zinc boxes with glass side walls, which contained the seedlings, on their sides on the stage of a dissecting microscope and by means of a camera lucida traced the magnified images on paper. In this method the object is subjected, during the time necessary for drawing, to a stimulus acting at right angles to the direction in which it acts during the intervals between drawings. If these intervals are short the curvature of the root may be materially changed and a curvature toward the side of the box will make its appearance, particularly if the experiment extend over considerable time. This lateral curvature will occasion inconvenience and probable inaccuracy in drawing the root and may bring it into contact with the side wall of the box. An arrangement by which the roots could be drawn without changing their position relative to gravity would be more satisfactory.

Professor Pfeffer suggested to me that a makeshift drawing apparatus, consisting of a camera, once part of a now obsolete photo-micrographic apparatus, the ground glass of which had been replaced by a piece of clear glass and which had been employed by an earlier student in the laboratory, might serve my

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purpose. A photographic lens of rather short focal length had been employed in this drawing camera and the image had been traced on a piece of almost transparent parchment paper held against the glass plate by means of two pieces of wood wedged into the ground glass frame.

I found it very difficult to trace accurately the image because the drawing surface was perpendicular. On that account I designed the attachment which is illustrated in the accompanying figures to bring the image into a horizontal plane. It was constructed by a photographic mechanician in Leipzig and was so made that it could be substituted for the ground glass frame of the camera by sliding it into the grooves which held the frame in place. The attachment consisted of a wooden box having approximately the form of a right triangular prism, two sides of which were open. One of these open sides was held against the back of the photographic camera. Into the other open side, which was horizontal when the box was in position, a glass plate (*g*) was fitted. On the inner surface of the hypotenuse side of the box a mirror (*m*) was fastened which reflected the pencil of light coming from the camera lens upward through the glass plate.

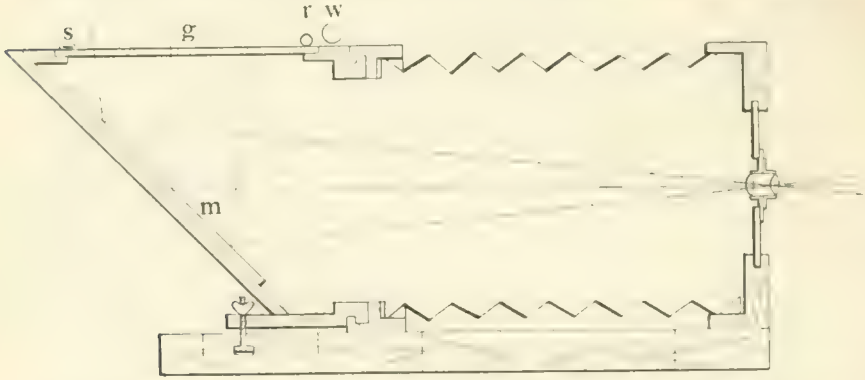

Fig. 1. Section through the drawing camera. One-sixth natural size. Explanation in the text.

A very satisfactory contrivance which I had constructed for stretching the parchment paper over the surface of the glass and keeping it free from wrinkles was attached to the reflecting box. This consisted of three parts. The roll (*w*) was made of wood and provided with a slit like a kodak film roll. It was attached by brackets just above the glass plate. The roll (*r*) consisted of a brass rod provided with a small crank at one end and covered for a length equal to the width of the glass plate with a piece of soft thick walled rubber tubing. This roll was so fastened to the frame that the tubing was compressed against the glass plate near its upper edge. The strip (*s*) of springy brass plate was bent into a flat curve and fastened by two screws at the left of the glass plate and near its lower edge. Over the strip several short pieces of soft rubber tubing were drawn. A metal tongue attached to the frame at the right made it possible to hold the brass strip against the glass plate.

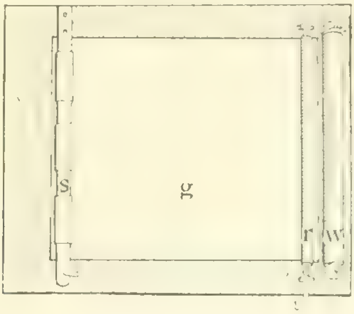

Fig. 2. Reflecting box as seen from above, showing arrangement for holding the parchment paper. Explanation in the text.

In use the parchment paper cut in strips of proper width and wound on the roll (*w*) was passed between the roll (*r*) and the glass plate. The end of the paper was then fastened at the lower end of the plate by means of the strip (*s*). A few backward turns of the roll (*r*) stretched the paper smoothly over the glass.

The whole apparatus rested upon wooden strips mounted on a laboratory stand the height of which could be adjusted by a crank. By sliding the camera along the strips it was possible to focus the image without changing the distance between the lens and the drawing surface. Thus a constant magnification could be maintained throughout a series.

The range of magnifications was $\frac{1}{2}\times$ to $2\frac{1}{2}\times$ but a conical extension made of sheet brass, which could be substituted for the lens board, so increased the distance of the lens from the surface on which the image was projected that magnifications of from $2\frac{1}{2}\times$ to $4\times$ could be secured when it was used.

The tracings obtained with this apparatus made it possible to follow the root curvature very satisfactorily. A piece of wire thrust into the cork on which a seedling was mounted and lying in the same plane as the geotropic curvature was traced each time the root was drawn. The tracing of the wire and of an India ink mark on the root base permitted the drawings of the curving root to be brought into perfect correspondence when they were superimposed. The position of the root relative to gravity was recorded by tracing the image of a plumb line on the first drawing of each series.

This camera has proven its usefulness in my own work, in the investigations of two other students at the Leipzig Institute on twining movements and orientation of leaves and in many of the exercises performed by students there, preliminary to the taking up of special problems. Many other uses for such a camera as well as improvements in design, particularly with reference to greater stability of the drawing surface, will suggest themselves to those interested.

# BOOKS AND CURRENT LITERATURE

XEROPHILY.—The inquiry as to what plants shall be designated xerophytes was made about a year ago by Kamerling[1] and has been more recently raised by Miss Delf.[2] The latter author has made a very careful answer to the question, showing that xerophytes have been defined in turn on habital, anatomical, and physiological evidence. Kamerling attempted to establish a purely physiological criterion for xerophily, based upon transpiration behavior. He measured the transpiration from severed shoots not supplied with water, a method which possesses the lowest grade of experimental value and could be useful only in the differentiation of an *Impatiens* and an *Opuntia*. Miss Delf repudiates the methods of Kamerling, and she furthermore rejects any attempt to give a purely physiological definition to xerophily. In such rejection she would doubtless include the suggestion of Bakke[3] that xerophily be defined in terms of the transpiring power of leaves, as measured by hygrometric paper. "It is clear," states Miss Delf, "that xerophily cannot be adequately defined in terms of habitat, of anatomy, or of physiology alone. It is rather a natural conception involving the total reaction of plant to environment." We have used the term "xerophyte" for 93 years and are now attempting to sort out the particular plants which belong in this category. Kamerling rejected the anatomical claims of *Casuarina* and *Sarothamnus scoparius* as xerophytes, and also the claims of mosses and lichens, in spite of their ability to withstand desiccation being greater than that of any flowering plants. Miss Delf's work has led to the removal of the halophytes from their former place among xerophytes. In this time-honored category are still to be found the desert succulents and the desert sclerophylls and microphylls. Enough is already known of the behavior of the last-named classes of plants to make it highly irrational to class them together from any standpoint except that of a community of habitat. The question that should be asked is not "which plants shall we call xerophytes," but "what do we know about the physiological behavior and habital requirements of the plants of arid habitats and of other plants which resemble them." The reviewer ventures to predict that as we come to know more about the comparative physiological and ecological behavior of plants—depending less upon inferences based on anatomy—we will have use for the term xerophyte only in extremely general discussions of vegetation.—FORREST SHREVE.

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[1] Kamerling, Z., Welche Pflanzen sollen wir Xerophyten nennen? Flora, **106**: 433–454, 1914.

[2] Delf, E. Marion, The Meaning of Xerophily. Jour. Ecol., **3**: 110–121, 1915.

[3] Bakke, A. L., Studies on the Transpiring Power of Plants as Indicated by the Method of Standardized Hygrometric Paper. Jour. Ecol., **2**: 145–173, 1914. See review in this journal, **18**: 222–224, August, 1915.

PLANT LIFE.—A particularly attractive volume for the amateur in natural science has been produced by Mr. Charles A. Hall in his Plant Life.[1] A phylogenetic order of treatment embraces the entire range of cryptogamic and phanerogamic plants; and some of the best-known facts of physiology, paleontology and general biology are introduced at appropriate places in the scheme. The treatment is characterized throughout by an enthusiasm which is calculated to hold the attention, but the author shows no desire to go very deeply into matters of cause and effect, as is evident in the discussion of insectivorous plants, transpiration, respiration, and some other subjects. The book is calculated to serve a very useful purpose, but at no time in its perusal will the reader suffer from the mental exertion of following technical details. The illustrations are very numerous, the photographs being excellent and the colored plates the best that have appeared in any recent popular botanical work.—FORREST SHREVE.

[1] Hall, Charles A., Plant Life. Pp. 380, figs. 80, plates 74 (50 in color). London, A. and C. Black, 1915 ($6.00).

# NOTES AND COMMENT

At the suggestion of one of our subscribers, and with the encouragement of several other persons, The Plant World announces the offering of two prizes for the best papers embodying original work in soil physics. The first prize will be $50 and the second $25, with the reservation of the right to withhold both prizes if no worthy papers are submitted, or to combine the prizes for the rewarding of a paper of exceptional merit. The conditions governing the award will be similar to those employed in connection with the prizes for papers on the water relations of plants, which were offered in April, 1915. The names of the judges who will appraise the submitted papers will be announced in a later issue. The contesting contributions should be in the hands of the Editor of The Plant World by December 1, 1916, and the announcement of the award will be made not later than March 1, 1917. The early announcement of this contest is made in the hope that an entire year will afford time for a vigorous competition.

In the second Supplement to the Monthly Weather Review (September, 1915) Professor J. Warren Smith, of Columbus, has published an extensive series of meteorological data and phenological observations made at Wauseon, in Northwestern Ohio, between 1873 and 1912 by Mr. Thomas Mikesell. The full records of daily minimum, mean and maximum temperatures and of daily precipitation have been published. The phenological data comprise observations on 16 kinds of wild and garden fruits, on 20 crop plants, on 48 trees, shrubs and vines, and on 114 herbaceous plants. Professor Smith has already published a paper on the effect of weather on the yield of corn (Monthly Weather Review, February, 1914), based upon Mr. Mikesell's records, but he has done nothing more in the present paper than to present all of the data in a concise form. A record of such vouchsafed accuracy, of such long duration, and covering nearly 200 species of plants, is of great value as a source of material for investigating the relation of climatic factors to plant activity.

Another paper of phenological interest is published in the second Supplement of the Weather Review by Mr. George N. Lamb, of the

Forest Service. He has constructed a calendar of the leafing, flowering and seeding of some 72 trees of the eastern United States. These results are presented in a diagrammatic form, and in such a manner as to show the dates of a given activity in the northern and southern portions of the range of a tree, without, however, showing the duration of any of the activities. The sources of information and the conventions of the chart are fully discussed and a bibliography of tree phenology for the eastern United States is appended.

The heavily forested portions of equatorial Africa form a relatively small percentage of the whole area of that continent. It is the contention of Captain C. H. Stigand, writing in the Geographical Journal (June, 1915), that the primitive agricultural methods of the natives are responsible for a great reduction in the area of forest. The fertility of newly cleared land and the rapid loss of this fertility under cultivation are responsible for continuous encroachments on the forest. The abandoned fields are occupied by grass and bush and are apparently unable to revert to forest so long as the forest front continues to be attacked. Several lines of evidence are adduced by Captain Stigand to show that extensive areas of forest have disappeared, probably during the last 600 years, in British East Africa, in Uganda, and in the northern portion of the Congo.

At the Philadelphia meeting of the American Association a group of men interested in ecology met informally to consider the advisability of organizing an American Ecological Society. The principal incentives toward the formation of such a society are the desire of animal and plant ecologists to have greater contact and the urgent need of summer field meetings. A committee was appointed to prepare a scheme of organization and to call a meeting of all ecologists interested in the proposed society, to be held in Columbus during convocation week in December of the present year. Those who are interested in the society but do not expect to attend the Columbus meeting should communicate with the Secretary of the organization committee, Dr. H. C. Cowles, University of Chicago, Chicago, Illinios.

# EFFECT OF VANILLIN AS A SOIL CONSTITUENT

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## INTRODUCTION

The effect of vanillin on plants in solution cultures, in pot cultures, and in field plots has been the subject of an investigation by the laboratory of Soil Fertility Investigations which was made necessary by the discovery of vanillin in soils.[1] Vanillin has the characteristics of an aldehyde, and exists in the seeds, roots, stem, leaves and grain of many plants.[2]

It is harmful to wheat seedlings in water cultures, even in such low concentrations as a few parts per million, and the plants are killed in solutions of 500 parts per million in a few days.[3] The toxic effect is less marked upon the tops of the wheat plants than upon their roots. Vanillin is also harmful in nutrient culture solutions composed of calcium acid phosphate, sodium nitrate, and potassium sulphate. It is an oxidizable substance and is less harmful in solutions of some of these nutrient salts than in others, especially those high in nitrate.[4] Sodium nitrate and calcium carbonate,[5] which themselves induce oxidation, ameliorate the harmfulness of vanillin.

The isolation of vanillin from soils and its harmfulness to plants in aqueous solutions has made a study of its effect in soils and under field conditions essential. The results of such experiments with cowpeas, garden peas, and string beans will now be

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[1] Shorey, E. C., Jour. Agr. Res., **1**: 357, 1914.

[2] See especially Sullivan, M. X., Jour. Ind. Eng. Chem., **6**: 909, 1914.

[3] Schreiner, Reed, and Skinner, Bull. 47, Bureau of Soils, U. S. Dept. Agr., 1908.

[4] Schreiner and Skinner, Bull. 77, Bureau of Soils, U. S. Dept. Agr., 1911.

[5] Schreiner and Reed, Am. Chem. Soc., **30**: 85, 1908.

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given, together with the action of vanillin on clover in soil in pots and with wheat plants grown in several soils of different characters.

## EFFECT OF VANILLIN ON SOILS IN POTS

An experiment to determine the effect of vanillin on clover was made by growing clover in Chester loam soil in large pots. Ordinary clay flower pots holding 6 pounds of soil were used. One pot was untreated; the other had a total of 300 parts per million of the vanillin added to it.

When the soil was potted, 100 parts per million of the vanillin were added and clover then sown, 0.5 gram of seed per pot. The clover was sown April 12, and came up well. On April 28, 50 parts per million of vanillin were added in solution through a funnel passing into the soil nearly to the bottom of the pot, thus avoiding direct contact with the tops or roots of the clover. In May 15, on June 1 and again on June 10, 50 parts per million were added, making the total application 300 parts per million. The experiment was discontinued June 21, 1912.

The effect of vanillin was noticeable from the first. The harmful effect is shown by comparing the untreated pot and the vanillin-treated pot shown in figure 1. The vanillin-treated plants were normal in appearance but stunted in growth. The green weight taken at the termination of the experiment was 8 grams from the untreated pot and only 3.8 grams from the vanillin-treated pot, a decrease of 53%.

The soil used in this experiment was a soil of moderate productiveness, and vanillin applied to it at different periods of the growth of the plants was distinctly harmful. Other experiments were made to test the effect of different amounts of vanillin in several soils, each having different properties and being of different geological origin. In the following experiments wheat was used as the test crop and the total application of vanillin was made before the soil was potted and seeds planted.

In this experiment the effect of vanillin in several soils was studied by growing wheat in pots. The soils used were infertile Florida sand, an infertile sample of Susquehanna sandy loam, and a good sample of Hagerstown loam. The paraffined wire pot method[6] was used, six wheat plants were grown in each pot, and two pots were used for each treatment. The plants grew from May 5 to May 24. Photographs of the growing plants were taken, which show the action of vanillin in each soil. At the end of the experiment the green weight was determined.

The Florida sand used in this experiment had grown citrus fruits in the field and was unproductive. A laboratory examination showed the soil to be acid. Vanillin was isolated from this soil in the investigations referred to above. The Susquehanna sandy loam was taken from an infertile area in Maryland. The natural growth on this soil was poor, and its response to fertilizer and cultural treatments was only moderate. Its oxidizing power and life activities were found to be very weak. The Hagerstown loam is a fertile soil. The soil was taken from a productive field of the Pennsylvania Agricultural Experiment Station. The soil is neutral in reaction, has strong oxidizing power, and grows thrifty plants in pots.

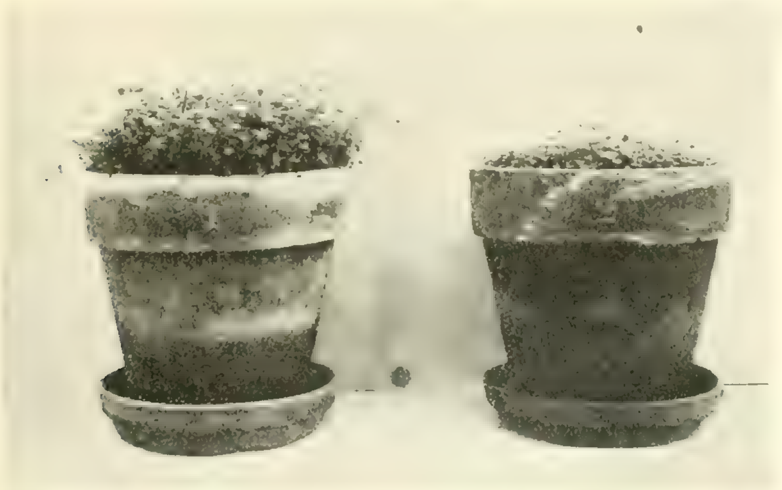

Fig. 1. Effect of vanillin on clover. (No. 1, Soil untreated. 2, Soil plus vanillin.)

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[6] Cir. 18, Bureau of Soils.

Vanillin was used in amounts of 100 to 500 parts per million. It was applied to the soil by dissolving in water and mixing the solution in the soil before potting. The results of the experiment on the effect of vanillin in the Florida sand, Susquehanna sandy loam, and Hagerstown loam are given in table 1. The actual green weight of the plants grown in the two pots are given for each treatment and the relative weight with the growth in the untreated soil taken as 100.

TABLE 1

*Effect of vanillin on wheat plants in pots grown in Florida sand, Susquehanna sandy loam, and in Hagerstown loam*

| TREATMENT | FLORIDA YELLOW SAND (INFERTILE SAND) | | SUSQUEHANNA SANDY LOAM (UNPRODUCTIVE SOIL) | | HAGERSTOWN LOAM (PRODUCTIVE SOIL) | |
|---|---|---|---|---|---|---|
| | Green weight | Relative weight | Green weight | Relative weight | Green weight | Relative weight |
| | *grams* | | *grams* | | *grams* | |
| Soil untreated........ | 1.40 | 100 | 1.80 | 100 | 1.98 | 100 |
| Soil + 100 p.p.m. vanillin | 1.32 | 94 | 1.85 | 103 | 1.87 | 94 |
| Soil + 200 p.p.m. vanillin. | 1.32 | 94 | 1.70 | 94 | 2.02 | 102 |
| Soil + 300 p.p.m. vanillin | 1.35 | 98 | 1.33 | 74 | 2.05 | 103 |
| Soil + 400 p.p.m. vanillin........ | 1.20 | 86 | 1.30 | 72 | 1.96 | 99 |
| Soil + 500 p.p.m. vanillin........ | 1.18 | 84 | 1.02 | 57 | 1.95 | 99 |

The vanillin was quite harmful in amounts of 400 and 500 parts per million in the Florida sand and was only moderately harmful in amounts of 100 to 300 parts per million. With the Susquehanna sandy loam the vanillin reduced growth considerably when applied at the rate of 300, 400, and 500 parts per million. It was slightly harmful with 100 and 200 parts per million. Vanillin had no harmful effect in the Hagerstown loam two of the treatments were slightly above the check and three slightly below. The growth in the untreated soil of the Hagerstown loam was better than in the Susquehanna sandy loam and considerably better than in the Florida sand.

It is seen from this experiment that vanillin is harmful in two of the soils and has no effect in the third. Vanillin is easily oxidized and changed under favorable conditions, and if this took place the action on plant growth would not be noticeable. In as much as the Florida sand was found to contain vanillin when sent in from the field it was to be expected that vanillin would persist in this soil, that added vanillin would not be changed and would remain as such to have its effect on plants grown in the soil. The Susquehanna sandy loam is also a soil having small oxidizing power and low life activity, and added quantities of vanillin apparently remained as such and had their effect on plant growth. The Hagerstown loam is a soil of entirely different characteristics, being highly productive, which indicates good life activities and good oxidizing power. Vanillin when added does not have harmful effects on plants grown in the soil, as it probably does not remain in this soil as such, but is changed or destroyed by the oxidation which is going on in soils of this character.

In order to study further the action of vanillin in soils and its bearing on soil fertility, the effect of vanillin under field conditions was tested in plots. Three leguminous crops—cowpeas, string beans, and garden peas—were grown to maturity in this experiment, with the following results:

### EFFECT OF VANILLIN ON COWPEAS, STRING BEANS, AND GARDEN PEAS GROWN IN THE FIELD

The effect of vanillin in soils under field conditions was tested on plots at the experiment farm of the Agricultural Department at Arlington, Virginia. Three crops were grown, namely, cowpeas, string beans, and garden peas. These experiments were made during the summer of 1913. The treated plot was adjoined on each side by an untreated plot growing the same crop. Each plot was 8¼ feet square, or one-fourth of a square rod. The soil on which these experiments were made is a silty clay loam, low in organic matter. The ground is level and has surface drainage. The soil throughout these plots and their controls is uniform, so the results secured should not be considered as unduly influenced by irregularities due to non-uniformity of the soil in different plots. The soil is of an acid nature. The land was plowed early in May and prepared for seeding.

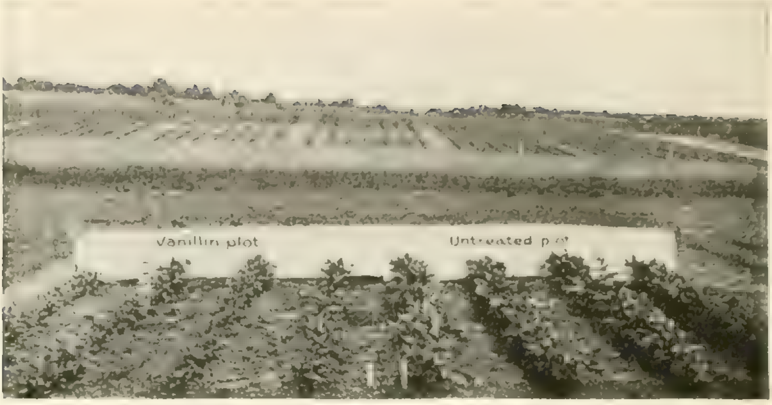

Fig. 2. Effect of vanillin on cowpeas in the field.

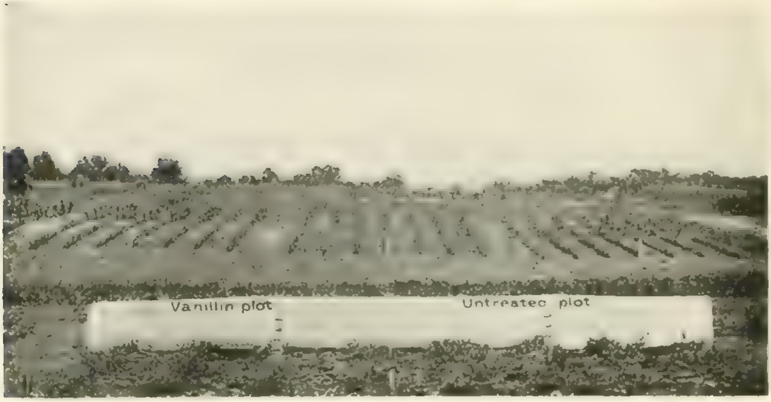

Fig. 3. Effect of vanillin on garden peas in the field.

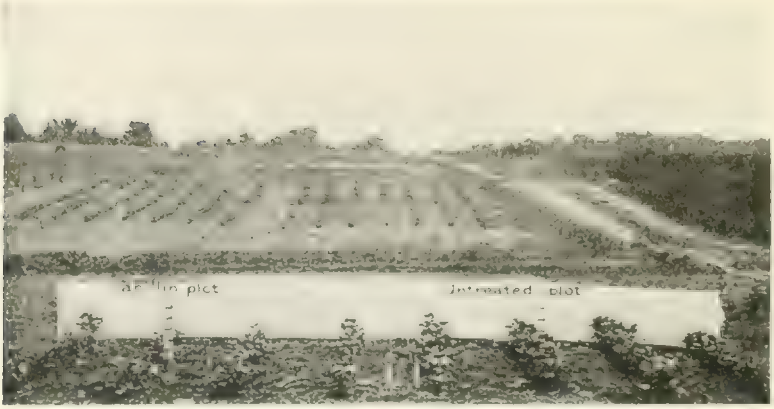

Fig. 4. Effect of vanillin on string beans in the field.

Four applications of vanillin were made. The first on May 20, one day before the planting of seed. The other three applications were made periodically during the growth of the crops—May 28, June 5, and June 24. The vanillin was applied by dissolving in water and sprinkling the solution uniformly on the surface of the ground before planting, after which the soil was raked thoroughly. The remaining applications were made after planting by sprinkling the solution between the rows of plants, the soil being subsequently cultivated. The total application was at the rate of 284 pounds per acre, in four equal parts.

TABLE 2

*Yield of cowpeas, garden peas and string beans as affected by vanillin in the field (yield per plot)*

| TREATMENT | COWPEAS | | | GARDEN PEAS | | | STRING BEANS | | |
|---|---|---|---|---|---|---|---|---|---|
| | Vines | | Pods | Vines | Peas | | Vines | Beans | |
| | Green | Cured | | | | | | | |
| | *pounds* | *pounds* | *pounds* | *pounds* | *pounds* | *pints* | *pounds* | *pounds* | *pints* |
| Check a | 28.0 | 10.0 | 6.6 | 1.72 | 1.66 | 4.50 | 3.55 | 1.90 | 4.75 |
| Check b | 23.0 | 8.5 | 5.6 | 1.50 | 1.48 | 4.00 | 2.94 | 1.66 | 4.15 |
| Average check | 25.5 | 9.3 | 6.1 | 1.61 | 1.57 | 4.25 | 3.24 | 1.78 | 4.45 |
| Vanillin | 17.0 | 5.7 | 4.0 | 1.12 | 1.14 | 3.00 | 2.71 | 0.55 | 1.50 |
| Difference | 8.5 | 3.6 | 2.1 | 0.49 | 0.43 | 1.25 | 0.53 | 1.23 | 2.95 |

The crops germinated uniformly. The effect of the vanillin was noticeable from the beginning and throughout the experiment. The growth was stunted, though the plants grew slowly to maturity, and were harvested. The three crops were sown on their respective plots May 21. The cowpeas were harvested September 27, the garden peas had matured by June 30, and were harvested on that date, and the string beans were harvested July 22. The yields of the various plots are given in table 2.

An examination of the table shows that vanillin checked growth and materially lessened the yield, with each of the crops. In the case of the cowpeas there was a reduction of 33% of green vines and 39% of cured hay. The garden peas were reduced 30% in vines and 20% in marketable peas. The string beans were reduced 17% in vines and 69% in beans. It was noticeable that the cowpeas growing on the vanillin-treated plot had a pale yellow color, and were weaker than on the check plot.

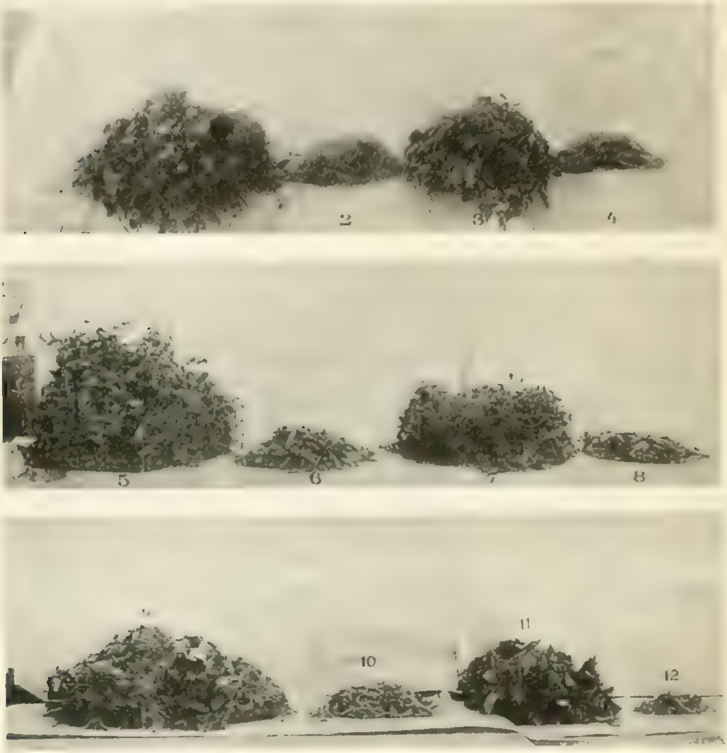

Fig. 5. Yield of cowpeas, garden peas, and string beans on check plot and vanillin-treated plot.

(1) Cowpea vines, (2) pods on check plot; (3) cowpea vines, (4) pods on vanillin plot; (5) garden pea vines, (6) pods on check plot; (7) garden pea vines, (8) pods on vanillin plot; (9) string bean vines, (10) beans on check plot; (11) string bean vines, (12) pods on vanillin plot.

The crops were photographed in the early stages of their growth, and are shown in figures 2, 3 and 4. In each figure the first four rows are growing on the plot to which vanillin was added and the last four rows are the check plot. Figure 2 shows the effect of the vanillin on cowpeas, figure 3 on garden peas, and figure 4 on string beans. The photographs show that even at this early stage of growth each of the crops is retarded by vanillin. When the crops were harvested the vines and pods from each plot were piled separately, and photographed together with the yield from one of its check plots. It is also shown here in the case of each crop that the vanillin treated plots yielded much less than the untreated soil. These photographs are shown in figure 5.

## PRESENCE OF VANILLIN AND ITS EFFECT IN THE SOIL SIX MONTHS AFTER APPLICATION

The question of the length of time the vanillin would persist in the Arlington soil and have an influence on its crop-producing power has also been investigated by a chemical study in the laboratory and by pot tests. Samples of soil for these purposes were obtained from the plots the last of November, six months after the substance was applied, and after it had matured a crop. The soils were examined for vanillin by the method already described by Shorey.[7] The method, in brief, consists of making an alkaline extract of the soil. The extract is acidified and filtered and then shaken out with ether. The aldehyde is removed from the ether by sodium bisulphide solution, acidified, and the liberated aldehyde again taken up in ether. The ether extract obtained by this process will contain aldehydes if present in the soil. Vanillin was found to be present in each of the soils from the plots to which the substance had been applied six months previously.

Pot tests were made in the soil from these plots, in order to determine if the vanillin still had an effect on growth. In these experiments, which were conducted by growing wheat, cowpeas, garden peas, and beans in small paraffined wire pots, it was found that each of the vanillin-treated pots produced poorer wheat than soil from the check plots. Wheat was reduced in growth 26% in the soil from the vanillin plot which grew cowpeas in the field, 25% in the treated soil which grew garden peas in the field, and 29% in the treated soil which grew string beans in the field.

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[7] Jour. Agr. Research, **1**: 357, 1914.

Cowpeas growing in pots in the soil which grew cowpeas in the field made 29% less growth in the soil treated with vanillin than in the soil from the check plot. Garden peas in the soil from the vanillin-garden pea field plot also made 29% less growth than in soil from the check plot, and string means made 6% less growth in the soil from the vanillin-string bean plot than in soil from its check plot.

The vanillin was still harmful to the respective crops six months after its application, and after it had produced the same crop in the field. These experiments show that vanillin persists in this heavy silty clay loam soil and affects its fertility for a considerable length of time.

# AN INVESTIGATION OF THE CAUSES OF AUTONOMIC MOVEMENTS IN SUCCULENT PLANTS

EDITH BELLAMY SHREVE

*Tucson, Arizona*

(Concluded)

## II.

Livingston and Brown[4] found that in the climate of southern Arizona (the habitat of the plants used in this research) "green plants when subjected to relatively great diurnal evaporation intensity, at least frequently, exhibit a marked fall in foliar moisture content by day and a corresponding rise by night." They found this true for several species of thin-leaved plants and for one succulent, *Trianthema portulacastrum.*, but failed to find it in two species of thick leaved xerophytes (*Covillea glutinosa* and *Prosopis velutina*). However, the present author[5] found it for *Parkinsonia microphylla*, which is a very thick leaved perennial. Lloyd[6] found the same result with leaves of Fouquieria splendens and working with cut shoots of the same species on burettes, he obtained a difference between water intake, as measured by the burette, and transpiration loss, as measured by loss of weight, which was negative for the day and positive for the night. In order to test the matter for this cactus experiments 9 and 10 were carried out.

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[4] Livingston, B. E. and Brown, W. H., Relation of the daily march of transpiration to variations in the water content of foliage leaves. Bot. Gaz. **53**: 309-330, 1912.

[5] Shreve, E. B., The daily march of transpiration in a desert perennial. Carnegie Inst. Wash. Pub. No. 194, 1914.

[6] Lloyd, F. E., The relation of transpiration and stomatal movements to the water content of leaves of *Fouquieria splendens*. The Plant World **15**: 1-14, 1912.

EXPERIMENT 9.

*Object:* (1) An investigation of the changes in turgidity between day and night, as measured by the difference between water-intake at the roots and water-loss by transpiration for the same period. (2) A comparison of the changes in turgidity with the movements of the joints.

TABLE 7

EXPERIMENT 9. *Correlation of movements of Opuntia and water-content of the tissues*

| TIME | T* | A* | WATER-CONTENT | | MOTION | | E* | LIGHT |
|---|---|---|---|---|---|---|---|---|
| | | | Gain | Loss | Up | Down | | |
| | | | | *Plant No. 13* | | | | |
| | *grams* | *grams* | *cc.* | *cc.* | *cm.* | *cm.* | *grams* | |
| June 28, 6 p.m. | | | | | | | | |
| June 29, 6 a.m. | 0.26 | 0.02 | 0.00 | 0.24 | 0.0 | 0.5 | 0.77 | ■ |
| June 29, 6 p.m. | 0.11 | 0.11 | 0.00 | 0.00 | 0.1 | 0.0 | 0.18 | □ |
| June 30, 6 a.m. | 0.38 | 0.04 | 0.00 | 0.34 | 0.0 | 1.1 | 0.67 | ■ |
| June 30, 6 p.m. | 0.11 | 0.34 | 0.23 | 0.00 | 1.0 | 0.0 | 1.36 | □ |
| | | | | *Plant No. 14* | | | | |
| June 28, 6 p.m. | | | | | | | | |
| June 29, 6 a.m. | 0.55 | 0.42 | 0.00 | 0.13 | 0.0 | 5.8 | 0.77 | ■ |
| June 29, 6 p.m. | 0.14 | 0.14 | 0.00 | 0.00 | 0.0 | 0.0 | 1.08 | □ |
| June 30, 6 a.m. | 0.33 | 0.27 | 0.00 | 0.06 | 0.0 | 2.8 | 0.67 | ■ |
| June 30, 6 p.m. | 0.07 | 0.20 | 0.13 | 0.00 | 5.2 | 0.0 | 1.36 | □ |
| July 1, 6 a.m. | 0.21 | 0.07 | 0.00 | 0.14 | 0.0 | 0.6 | 0.46 | ■ |
| July 5, 7 p.m. | | | | | | | | |
| July 6, 7 a.m. | 0.14 | 0.02 | 0.00 | 0.12 | 0.0 | 0.7 | 0.46 | ■ |
| July 6, 6 p.m. | 0.96 | 0.51 | 0.00 | 0.45 | 0.0 | 19.9 | 4.50 | □ |
| July 7, 7 a.m. | 0.62 | 0.87 | 0.25 | 0.00 | 6.9 | 0.0 | 1.14 | ■ |
| July 7, 6 p.m. | 0.81 | 0.33 | 0.00 | 0.48 | 0.0 | 7.8 | 4.95 | □ |
| July 11, 6 a.m. | 0.94 | 2.04 | 1.10 | 0.00 | 21.8 | 0.0 | 1.77 | ■ |

* T = total transpiration for the period indicated.
A = total absorption for the period indicated.
E = water loss per hour from standard atmometer.

*Material:* Plants Nos. 13 and 14. No. 13 had been growing in the open until a month before the time of the experiment, when it was cut off just above the roots and placed with its lower end in a bottle of water. As soon as a large fibrous root system had developed in the water the plant was considered ready for use. No. 14 was a two year old individual which had been raised from seed in the green-house. It was removed from the bed with a large fleshy root intact and placed with its roots in a second bottle of water. Many of the small roots were broken at the time of removal from the soil but measurements were not begun until an abundant supply of fibrous roots had been formed.

*Method:* Nos. 13 and 14 were sealed in separate bottles in the following way. Each bottle was completely filled with water. A rubber stopper containing three holes, one for the plant stem, one for a burette and one for a thermometer, was cut into two pieces and then forced into place around the woody part of the stem until the system was air-tight. The water in the burette rose above the general level and was adjusted to a convenient height. The burette was of narrow diameter, being graduated to 0.01 cc. with a possibility of readings being estimated to 0.001 cc.

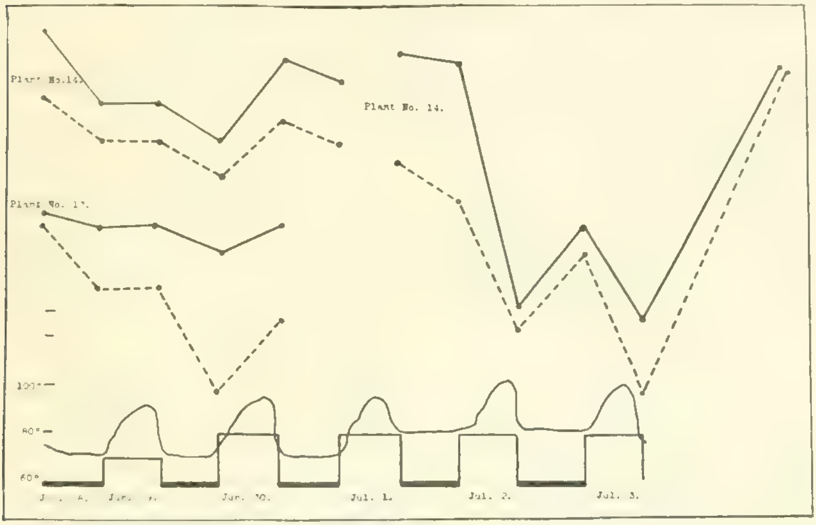

Fig. 7. Correlation of movements of joints and changes in turgidity of the plant. Solid line, movements. Broken line, water-content changes. June 28 to July 1, evaporation of average intensity. July 1–3, evaporation of unusually high intensity. Two lowest graphs indicate temperature and light conditions. See experiment 9.

At the beginning and end of each period the entire bottle with the plant was weighed for the determination of the loss from transpiration. Atmometers of the Livingston type were used, for the measurement of evaporation. In order to determine the amount of water taken up by the roots, the height of the liquid in the burette was read at each period and the difference between the readings, after it was corrected for contraction and expansion of volume due to temperature changes, represented the amount of water absorbed by the roots.

The correction for expansion and contraction was found by means of two control bottles of the same capacity as the ones containing the plants. These bottles were filled with water and fitted up in all respects like the ones holding the plants. By means of twenty readings extending over several days the amount of change in volume per degree, for the temperatures used, was found from measurements of the changes in height of the water in the burettes and of the corresponding temperature changes. The twenty readings showed a maximum difference of 4% in the value of the change of volume per degree. A correction factor of 0.157 cc. per degree was found by averaging twenty readings. At each reading for the water-intake of the plant, the temperature of the water was read and thus the total amount of temperature change for the period found. The change in volume per degree, as determined above, was then multiplied by the number of degrees of change the water had undergone and this correction subtracted from the total change in level. The tables contain the corrected amount of water absorbed.

The difference between absorption and transpiration gives the gain or loss in water-content of the plant. These changes in water-content have been plotted and appear in figure 7. A convenient point on the paper was selected to represent the original water-content and, using this as a starting point for plotting the losses or gains, each new loss or gain was measured from the point immediately preceding it. Measurements of the positions were made, as formerly, with a meter-stick.

*Results:* From table 7, it is seen that under average evaporative intensity and with the normal day to night changes in light intensity and air temperature the plants lose more water at night than they take up at the roots, and in the day they take up more than they lose by transpiration. This means nothing else than that the turgidity of the plant increases during the day and decreases during the night. Simultaneous measurements of the position of joints show that increased turgidity is accompanied by a rise and decreased turgidity by a drop of the joint.

The measurements taken on July 5-6, under increased evaporative conditions show, as in experiment 7, that the movements for day and night have been reversed and, what is more important, the results of these days show that the turgidity changes still parallel the movements.

Thus the evidence is that the short period movements are the direct result of turgidity changes. In order to gain further proof of this fact the same kind of measurements were taken in the next experiment by different methods.

EXPERIMENT 10.

*Object:* The simultaneous measurement of water-content changes and the movement of joints.

*Material:* Plants Nos. 30, 31, 32, and 34. They varied in age from about three to eight years. All were transplanted from the open about eight weeks before the beginning of the experiment. They became well established in their new environment, as was shown by the considerable growth they made. During the experiment their pots were kept saturated with water.

*Method:* The movements were measured by means of automatic pen tracings on a drum. Figure 9 shows the details of the arrangement. The apparatus has been described in a slightly different form by MacDougal[7] and has recently been used by him for the growth measurements of Platyopuntias, with the lever arm resting directly upon the joints. In order to adopt the apparatus to the measurement of the movements it was necessary to make the lever which touches the joints longer than the pen lever, in order to reduce the magnitude of the movement enough to get the whole tracing on the drum. These tracings have been reduced and appear in figure 8.

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[7] MacDougal, D. T., Practical text-book of plant physiology. (Longmans Green and Co.), p. 291.

The measurement of water-intake and out-go was made by a method devised by Briggs and Shantz[8] for the determination of the wilting point of succulent plants. Briefly, the method consists in balancing the plant upon a knife edge which is fastened at the juncture of pot and plant. The system is balanced in a horizontal position by means of a movable screw; and then immediately returned to a vertical position, where it remains until the close of the period considered. At this time its point of equilibrium is again tested in the horizontal position. The pot is sealed so that it can lose no water except to the plant. As the plant loses water through transpiration, water moves from the soil and replaces that lost by the plant and the pot side of the system becomes lighter and rises. This process is repeated as often as the system is restored to equilibrium by means of the movable screw. If the plant does not obtain enough water to replace the loss from transpiration the aerial side of the system will rise. The authors state that by determining the loss in weight from the entire system on a pair of balances and comparing this with the weight which, when placed at the center of pot or aerial part of the plant, will restore equilibrium, absorption and transpiration can be separated. This is true provided the conducting system is able to pass up the water as fast as the roots take it in.

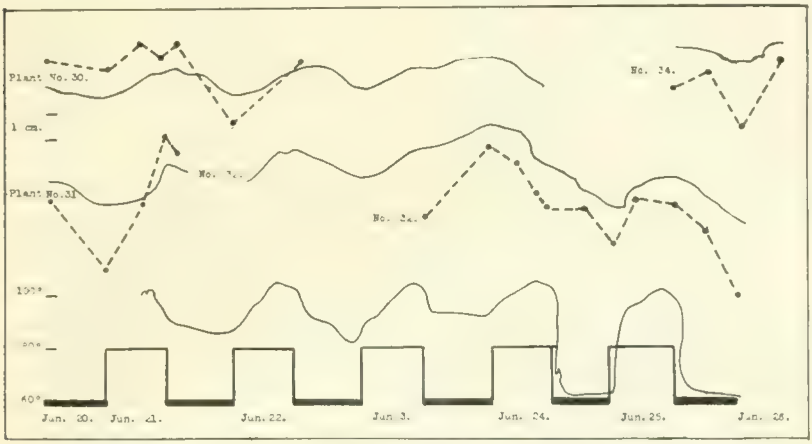

Fig. 8. Correlation of movements of joints and turgidity changes in the plant. Solid line, movements. Broken line, water-content changes. Two lowest graphs indicate temperature and light conditions. See experiment 10.

The calculation is not quite so simple as might be supposed from the author's statement. Furthermore, the accuracy of the results is limited by the fact that an estimation of the center of transpiration loss must be made, and this involves two sources of error, the first being that it must be assumed that all of the upper part of the plant transpires at the same rate, and the second that there is difficulty in determining the volumetric center of the aerial parts. It is possible to find a probable maximum error by supposing the center of transpiration which is selected, to be wrong a given proportion of the length of the plant, first in one direction and then in the other.

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[8] Briggs, L. J. and Shantz, H. L., The wilting coefficient for different plants and its indirect determination. Dept. Agr. Bur. Plant Ind. Bull. No. 230, pp. 47–51.

An example will best illustrate the method of calculation. From table 8 it is found that Plant No. 30, the centers of whose pot and aerial parts are 5.5 cm. and 15 cm. from the knife edge, showed the following readings on the night of June 22–23. At 8.51 p.m. the system was balanced by means of the screw and then weighed as a whole on balances. At 8.29 a.m. the next morning the plant

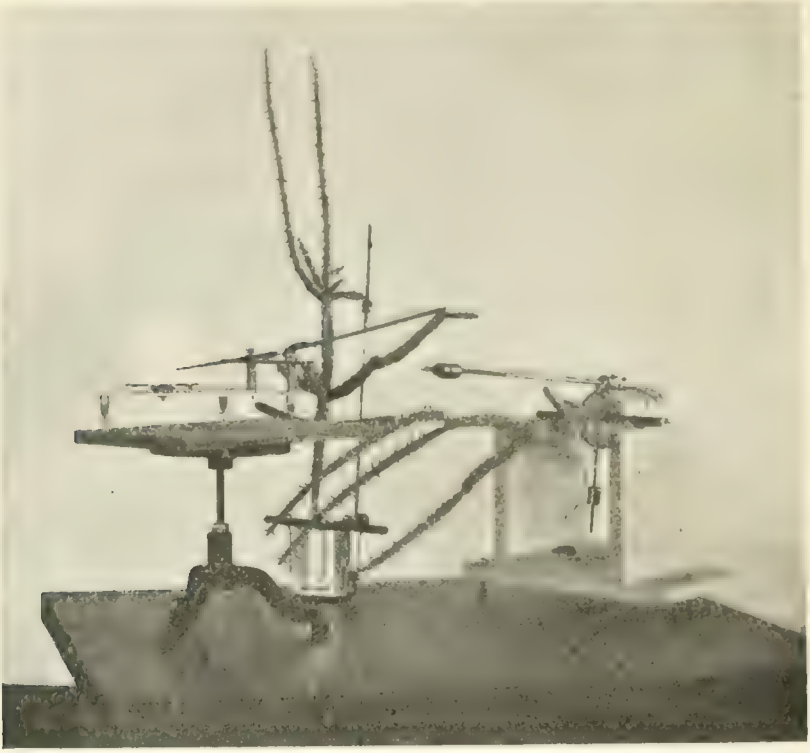

Fig. 9. Apparatus used for the determination of transpiration and absorption in experiment 10. At the left may be seen the device for automatically recording the movements of joints.

was taken from the dark room and again placed in a horizontal position, resting upon its knife edge. The plant rose so that no point of equilibrium could be found, showing that the plant had lost more water than it had gained from the soil during the night. When 3.5 grams were placed on the pointer at a distance of 5.5 cm. from the knife edge the system was restored to equilibrium. The balances showed that the system had lost 5.5 grams during the period. If the equation $a=a$ represents the condition of equilibrium at 8.51 p.m. and $x$ the amount

TABLE 8

**Experiment 10.** *Correlation of movements of Opuntia and water-content of tissues*

T = total transpiration for the period indicated. A = total transpiration for the period indicated. E = water loss per hour from standard atmometer.

| TIME | T | A | MAXIMUM ERROR FOR A | WATER-CONTENT | |
|---|---|---|---|---|---|
| | | | | Gain | Loss |
| | | | *Plant No. 30* | | |
| | *grams* | *grams* | *grams* | *grams* | *grams* |
| June 20, 8 p.m. | | | | | |
| June 21, 8 a.m. | 3.6 | 3.3 | +0.1<br>−0.05 | 0.0 | 0.3 |
| June 21, 12 m. | 1.2 | 2.0 | ±0.2 | 0.8 | 0.0 |
| June 21, 4 p.m. | 0.9 | 0.5 | ±0.1 | 0.0 | 0.4 |
| June 21, 9 p.m. | 0.8 | 1.0 | ±0.1 | 0.2 | 0.0 |
| June 22, 8 a.m. | 5.5 | 3.1 | +0.4<br>−0.7 | 0.0 | 2.4 |
| June 22, 12 m. | 0.9 | 1.8 | ±0.2 | 0.9 | 0.0 |
| June 22, 7 p.m. | 1.2 | 2.3 | +0.4<br>−0.2 | 1.1 | 0.0 |
| June 23, 7 a.m. | | | | | |
| June 23, 12 m. | 1.5 | 1.5 | +0.3<br>−0.03 | 0.0 | 0.0 |
| June 23, 4 p.m. | 0.8 | 0.9 | ±0.04 | 0.1 | 0.0 |
| | | | *Plant No. 31* | | |
| June 20, 8 p.m. | | | | | |
| June 21, 8 a.m. | 5.1 | 3.2 | +0.3<br>−1.1 | 0.0 | 1.9 |
| June 21, 12 m. | 0.5 | 2.4 | +0.7<br>−1.1 | 1.9 | 0.0 |
| June 21, 4 p.m. | 0.7 | 2.7 | ±0.4 | 2.0 | 0.0 |
| June 21, 7 p.m. | 0.4 | 0.0 | ±0.02 | 0.0 | 0.4 |
| | | | *Plant No. 32* | | |
| June 23, 8 p.m. | | | | | |
| June 24, 8 a.m. | 3.4 | 8.0 | +0.2<br>−0.4 | 4.6 | 0.0 |
| June 24, 12 m. | 5.3 | 3.8 | +0.8<br>−0.2 | 0.0 | 1.5 |
| June 24, 4 p.m. | 3.4 | 1.8 | ±0.2 | 0.0 | 1.6 |
| June 24, 7 p.m. | 5.4 | 4.4 | +0.8<br>−0.2 | 0.0 | 1.0 |
| June 24, 11 p.m. | 0.5 | 0.5 | ±0.06 | 0.0 | 0.0 |

TABLE 8—Continued

| TIME | T | A | MAXIMUM ERROR OF A | WATER CONTENT |  |
|---|---|---|---|---|---|
|  |  |  |  | Gain | Loss |
| *Plant No. 32—Continued* |  |  |  |  |  |
|  | *grams* | *grams* | *grams* | *grams* | *grams* |
| June 25, 5 a.m. | 4.5 | 2.0 | +0.8<br>−0.5 | 0.0 | 2.5 |
| June 25, 9 a.m. | 3.2 | 6.1 | +0.5<br>−0.3 | 2.9 | 0.0 |
| June 25, 5 p.m. | 10.2 | 9.6 | ±0.1 | 0.0 | 0.6 |
| June 25, 11 p.m. | 3.6 | 2.8 | ±0.1 | 0.0 | 0.8 |
| June 26, 5 a.m. | 7.3 | 4.9 | ±0.3 | 0.0 | 2.4 |
| June 26, 7 a.m. | 2.5 | 2.5 |  | 0.0 | 0.0 |
| *Plant No. 34* |  |  |  |  |  |
| June 20, 8 p.m. |  |  |  |  |  |
| June 21, 8 a.m. | 3.6 | 3.3 | +0.1<br>−0.05 | 0.0 | 0.3 |
| June 21, 12 m. | 1.2 | 2.0 | ± 0.2 | 0.8 | 0.0 |
| June 21, 4 p.m. | 0.9 | 0.5 | ±0.1 | 0.0 | 0.4 |
| June 21, 9 p.m. | 0.8 | 1.0 | ±0.1 | 0.2 | 0.0 |
| June 22, 8 a.m. | 5.5 | 3.1 | +0.1<br>−0.7 | 0.0 | 2.4 |
| June 22, 12 m. | 0.9 | 1.8 | ±0.2 | 0.9 | 0.0 |
| June 22, 7 p.m. | 1.2 | 2.3 | +0.4<br>−0.2 | 1.1 | 0.0 |
| June 23, 7 a.m. | Condensation of water vapor on pots |  |  |  |  |
| June 23, 12 m. | 1.5 | 1.5 | +0.3<br>−0.03 | 0.0 | 0.0 |
| June 23, 4 p.m. | 0.8 | 0.9 | ±0.4 | 0.1 | 0.0 |

in grams transferred from pot to aerial part of the plant during the night than at 8.29 a.m. the condition of equilibrium will be represented by the equation

$$a - x\ (5.5) = a + x\ (15) + 3.5\ (5.5) - 5.5\ (15)$$
$$x = 3.1$$

That is, transpiration was 2.5 grams greater than absorbtion. In the above calculation the weight is in every case multiplied by its distance from the knife edge. The maximum error for this plant was calculated by considering the estimated center to be 5 cm. wrong first to the right and then to the left. Thus a total error is calculated which allows for an error in the center of the transpiring parts amounting to one-third of the length of the plant.

A few minor changes were made in the form of the apparatus as described by Briggs and Shantz. The apparatus used in the present work is shown in figure 9.

The devise for fastening the knife edge to the pot, which is shown in the illustration, was found to be much more satisfactory than the cement sealing recommended by the authors. The glass pots used by these same authors were not suitable for the present work. Consequently, the plants were allowed to become established in galvanized iron cylinders in the bottoms of which holes were punched for drainage. At the time of the experiment the bottoms of the cylinders were sealed with galvanized iron caps held in place and made airtight by plastocene. The sealing for the tops of the pots was made with heavy cardboard cut to fit and made airtight by a thick layer of plastocene. A rubber stopper was fastened with wire around the woody base of the plant so that the plastocene might not come in contact with the plant surface. All plastocene was completely covered with tin-foil, in order to avoid errors from dust, knocks etc.

*Results:* The same facts appear as in former experiments (1) Under normal conditions, the plant loses more water at night than it absorbs, and in the day time it absorbs more than it loses. This means that its turgidity is less at night than in the day time. (2) In all cases lessened turgidity is accompanied by a downward movement of joints and increased turgidity by an upward movement.

The agreement of the results from this experiment with those obtained in experiment 9, where the actual amount of water absorbed by the roots was measured directly, shows the correctness of the assumption made above, namely, the conducting tissue must be able to pass up water as fast as it is absorbed by the roots. Consequently the amounts under the heading A in table 7 are a true approximation of the water absorbed by the plant.

Although it is aside from the subject considered in this paper it seems worth noting that this last experiment shows that when wilting point determinations of cacti are made by the Briggs and Shantz method, care must be taken that readings are made at the corresponding hour each day, since any reading taken for an interval in which the night occupied the greatest part of the period might show an apparent wilting point when the plant was still obtaining its normal amount of water from the soil.

Such changes in turgidity as the last experiments have shown to exist, would probably cause both longitudinal and radial expansion and contraction of joints. Some joints are for a time in a vertical position and at that time show no upward and downward movement. Joints in a vertical position were chosen as subjects on which to detect contraction and expansion. Measurements of length with a meter stick and of diameters with a vernier caliper gave no evidence of such changes; but the automatic method of magnification used in the next experiment showed them clearly.

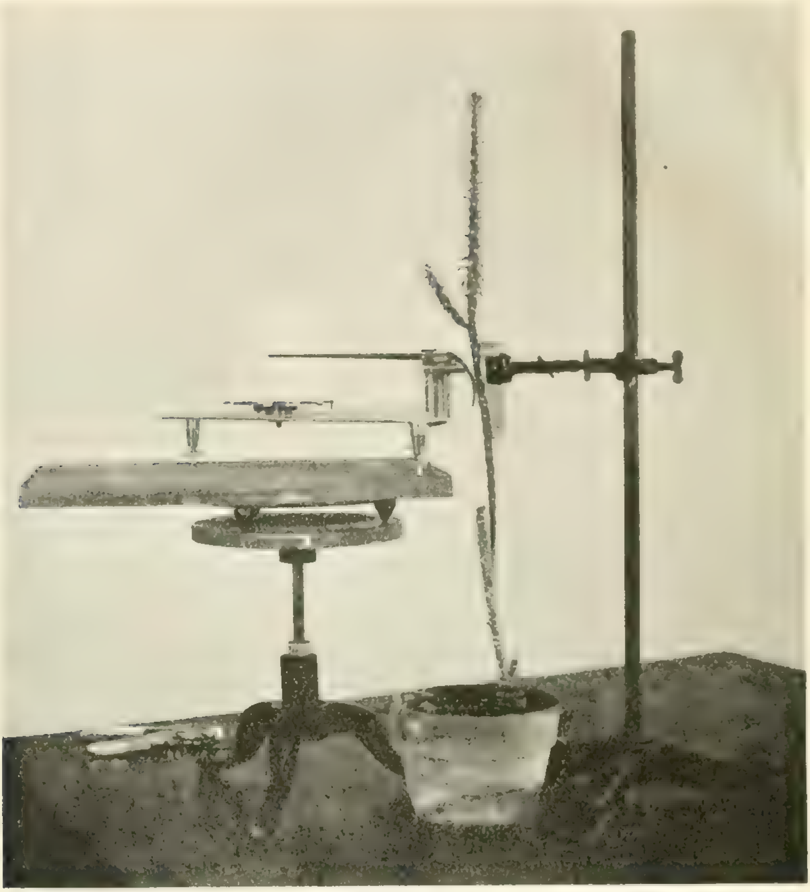

Fig. 10. A device for automatically measuring radial expansion and contraction of joints. See experiment 11.

EXPERIMENT 11.

*Object:* The discovery of any longitudinal and radial contraction which may take place from day to night, under normal conditions.

*Material:* Plants Nos. 18 and 19. They were both potted plants having vertical joints. No. 18 had a joint which was grown in the green-house and No. 19 had made its entire growth in the open.

*Method:* The apparatus which was used is shown in figure 10, where it is in the position to measure radial expansion and contraction. The part of the joint immediately opposite the point of contact of the lever which moves the recording pen, was imbedded in a plaster of paris jacket, so that it might be held in place firmly. For the measurement of the longitudinal changes the end of the curved lever was bent up until it rested in the same horizontal plane with the pen and its end then placed on the tip of the joint.

*Results:* The records from the tracings have been transferred to coördinate paper and appear in figure 11. The recording pen magnified the changes about three times and the actual maximum difference is size between day and night was about 0.15 cm. in both the radial and longitudinal directions.

All of the records show an expansion for the day and a contraction for the night. The changes on cloudy days were less than on bright days.

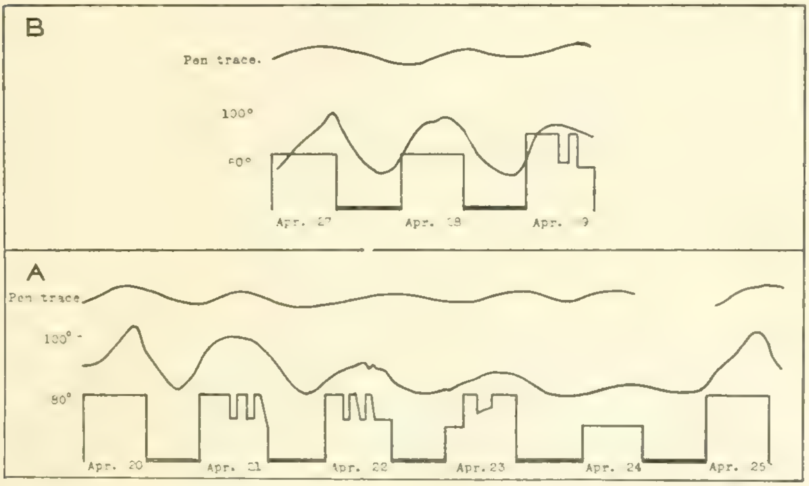

Fig. 11 A. A copy of an automatic pen trace (topmost curve) showing radial contraction and expansion of a joint. See experiment 11.

Fig. 11 B. A copy of an automatic pen trace (topmost curve) showing longitudinal expansion and contraction of a joint. Two lowest graphs indicate temperature and light conditions. See experiment 11.

Direct determinations of the water-content were attempted by heating joints to constant weight at 100°C. and calculating the original water-content per gram of dry weight. The individual variations of the joints were so great that any day to night changes were masked. However, the results of experiments 10 and 11 show that a difference in water-content does exist and there is no need of further proof that turgor is greatest in the day time when normal conditions exist. Thus the shorter period movements, as well as the longer ones, have been shown to be due to turgor changes.

What factors cause the day to night turgor changes, i.e., why the difference between absorption and transpiration is positive in the day and negative at night is of course another question. The author is now at work upon these more fundamental causes and will report upon the progress of the work at an early date.

That the phenomena which have been studied in *Opuntia versicolor* are practically universal for *Opuntia* seems probable from measurements which have been made on other species. The seasonal movement has been observed in the following: *Opuntia fusicaulis*, *O. fulgida*, *O. mamillata*, *O. tetracantha*, *O. arbuscula*, *O. leptocaulis*, *O. bigelovii*, all of the cylindrical form, and in *O. laevis*, *O. blakeana*, *O. linguiformis*, *O. fusicaulis, and O. monacantha*, of the flat-jointed type. The day to night movement has been measured on *O. lepticaulis*, *O. fusicaulis, and O. monacantha* and found to be the same as for *O. versicolor*.

## SUMMARY

(1) Twelve species of *Opuntia* and also *Carnegiea gigantea*, have been found to show seasonal movements of stems and branches, which consist of a drop during desiccation and a rise during recovery. These movements have been correlated with turgidity changes.

(2) The form of the adult cactus plant and the position of its branches is determined by the water relations existing during the period of growth and secondary thickening of its various parts and not by any peculiarities residing in its growing point or in its mode of initiating branches.

(3) *Opuntia versicolor*, *O. fusicaulis*, and *O. leptocaulis* were measured for the investigation of a short period movement which is shown to consist of an upward movement during the day and a downward one at night, when normal conditions of temperature, light intensity, soil-water content, and evaporative power of the air, exist.

(4) A detailed study of *Opuntia versicolor* showed that this short period movement is influenced by temperature, light intensity, evaporative power of the air, and the water-content of

both soil and plant tissues. The influence of these factors is indirect and acts through other intermediate processes.

(5) The day-to-night movements have been shown to be caused directly by turgidity changes.

(6) *Opuntia versicolor* is less turgid at night than in the day time as is shown by the fact that the plant absorbs more water through its roots in the day time than it loses by transpiration, and at night loses more than it absorbs. This is the opposite of the behavior shown by all non-succulents which have been studied.

# BOOKS AND CURRENT LITERATURE

Chemistry of Colloids.—The want of a text book of colloids in English has been long felt and much discussed. Recently Dr. W. W. Taylor of Edinburgh University has been moved to supply it and his volume, issued early in this year, is at hand.[1] The work is most creditable. In aim and content it stands between the admirable but brief treatment of Hatschek[2] and the larger detailed treatises of Freundlich,[3] Oswald[4] and Zsigmondy.[5] For the colloid specialist these latter works will remain indispensible. The greatest usefulness of Dr. Taylor's volume will be in the hands of those workers in chemistry, biology and adjoining fields who are finding more and more necessary some knowledge of colloids and their behavior. For the needs of these readers the book is a model of selection and condensation and the well chosen references to original literature furnish ample guides when more detailed information is necessary.

The book is in four parts. First are 163 pages devoted to the general properties, behavior and relations of colloidal systems. Following are 56 pages on the preparation of typical colloids, especially the metallic sols. The directions are detailed and practical and will be most helpful to those inexperienced in the difficult art of preparing stable colloidal solutions. The third part, of 42 pages, discusses adsorption and surface phenomena in general, excluding, however, any specific treatment of catalysis at surfaces. The fourth and last part (56 pages) is devoted to applications of colloid chemistry and includes chapters on casein, soaps and other semi-colloids; on the phenomena and theories of dyeing; on tanning, the colloids of the soil and the purification of waste waters and sewage; and on the applications of colloid chemistry to biology.

[1] Taylor, W. W., The Chemistry of Colloids. Pp.328. New York, Longman Green and Company, 1915.

[2] An Introduction to the Physics and Chemistry of Colloids. Pp. 87. Philadelphia, 1913.

[3] Kapillarchemie. Pp. 565. Leipzig, 1909.

[4] Grundniss der Kolloidchemie, 2nd edition. Pp. 329. Dresden, 1911.

[5] Kolloidchemie. Pp. 281. Leipzig, 1912.

Two sections of this fourth part are of especial interest to readers of these columns: the paragraph on soil colloids and the discussion of applications to biology. The former is very short (3 pages) and cannot be commended. There are assumed without argument the conception of humus as a definite colloidal substance and the idea of the usual existence of colloidal (gel) silica in the soil, from both of which assumptions the reviewer vigorously dissents. Under the applications of colloid chemistry to biology Dr. Taylor discusses the equilibrium between blood and oxygen; enzymes and the colloidal "inorganic ferments" of Bredig; the phenomena of bacterial agglutination; and the relations of toxins and antitoxins. To the biologist the treatment of all of these subjects (except, perhaps, the oxygenation of the blood) will seem sketchy and without proper perspective. Dr. Taylor's touch is here far less sure than in his treatment of the subject matter of colloid chemistry proper. One gathers that he has been interested rather in finding biological illustrations of colloid principles than in securing from colloid chemistry aid in the solution of biologic problems. One misses, also, any treatment of the swelling and shrinking of organic gels—of imbibition and the water relations of living matter and the associated non-living tissues. It would be too much to expect the detailed discussion of these matters in a volume of the restricted size and scope of Dr. Taylor's, but it is to be hoped that the examination and presentation of this important and disputed subject will be undertaken soon by some biological colloid chemist or some "colloidal" biologist.

In the reviewer's opinion Dr. Taylor's book is to be recommended to biologists not because of what it says of biology but because of what it says of colloid chemistry. Nevertheless it *is* to be recommended and that most insistently. If it accomplishes nothing else its perusal may induce biologists to refrain from ascribing to convenient "colloidal" actions all phenomena which they fail to understand. E. E. FREE.

# NOTES AND COMMENT

The Editor of Science includes in botany forty of the doctorates conferred by American Universities in 1915 (Science **42**: 555, 1915), but the following list is intended to comprise the titles which may be considered appropriate for review in botanical journals, of which there are forty-five as against a corrected estimate of thirty-eight in 1914. Some of the titles are comprehensive and indicate subjects which pertain to more than one of the main divisions of botany, but about twenty-three appear to be of a physiological character, seven morphological and embryological, six pathological, five ecological, two taxonomic, and two genetical. The relative interest in the various phases of botany is well illustrated by these figures. It is notable that all of the five doctorates from Washington University are in the botanical list, indicative of the activity of the Missouri Botanical Garden in promoting research in the institution with which it is allied. If the experience of previous years is to be taken as an index many of these theses will not reach publication for several months, and may be held for a few years before being put into print. An effort will be made to collect information concerning their publication.

## CORNELL UNIVERSITY

Elmer Eugene Barker. Heredity Studies in the Morning Glory (*Ipomœa purpurea*).

Harry Phillip Brown. Growth Studies in Forest Trees.

Leonard Amby Maynard. The Fixation of Nitrogen by Sweet Clover.

George Adin Osner. Leaf Smut of Timothy.

James Kemp Plummer. The Effect of Oxygen and Carbon Dioxide on Nitrification and Ammonification in Soils.

William Jacob Robbins. Digestion of Starch by *Penicillium* (*Camembertii*).

Joseph Rosenbaum. The Phytophthora Disease of Ginseng.

Constantine Demetry Sherbakoff. Fusaria of Potatoes.

James Kennith Wilson. Physiological Studies of *Bacillus radicola* of Soy Bean (*Sojus max* Piper) and of Factors influencing Nodule Production.

## UNIVERSITY OF CHICAGO

Hanna Caroline Aase. Vascular Anatomy of the "Megasporophyll" in Conifers.

Joseph Stuart Caldwell. A Study of the Effects of Certain Antagonistic Solutions upon the growth of *Zea Mays*.

Hermann Bacher Deutsch. Effect of Light upon the Germination of the Spores of the True Ferns.

James Frederick Groves. Life Duration of Seeds.

Andrew Henderson Hutchinson. Fertilization in *Abies balsamea*.

Eva Ormenta Schley. Physical and Chemical Changes Involved in Geo-presentation and Geo-reaction.

James Palm Stober. A Comparative Study of Winter and Summer Leaves of Various Herbs.

### WASHINGTON UNIVERSITY

Alva Raymond Davis. Enzyme Action in the Marine Algae.

William Harrison Emig. The Occurrence in Nature of Certain Fungi Pathogenic for Man and the Higher Animals.

Joseph Charles Gilman. Cabbage Yellows and the Relation of Temperature to Its Occurrence.

Melvin Clarence Merrill. The Electrolytic Determination of Exosmosis from the Roots of Plants Subjected to the Action of Various Agents.

Lee Oras Overholts. Comparative Studies in the Polyporaceae.

### UNIVERSITY OF ILLINOIS

Demetrius Ion Andronescu. The Physiology of the Pollen of *Zea Mays* with Special Regard to Vitality.

William Leonidas Burlison. Availability of Mineral Phosphates for Plant Nutrition.

Fred Weaver Muncie. The Effect of Large Applications of Commercial Fertilizers upon Carnations.

George Leo Peltier. Parasitic Rhizoctonias in America.

### THE JOHNS HOPKINS UNIVERSITY

Grace Adelaide Dunn. A Study of the Development of *Halosaccion ramentaceum*.

Forman Taylor McLean. A Preliminary Study of Climatic Conditions in Maryland as Related to the Growth of Soy Bean Seedlings.

John Wesley Shive. A Study of Physiological Balance in Nutrient Media Resulting in a Simplified Culture Solution for Plants.

### UNIVERSITY OF PENNSYLVANIA

John Young Pennypacker. Observations on the Beach Plum. A Study in Plant Variation.

David Walter Steckbeck. Comparative Histology and Irritability of Sensitive Plants.

Heber Wilkinson Youngken. The Comparative Morphology, Taxonomy and Distribution of the Myricaceae of the Eastern United States.

### UNIVERSITY OF CALIFORNIA

Richards Morris Holman. The Orientation of Terrestrial Roots with Particular Reference to the Medium in Which They Are Grown.

Harry Stanley Yates. The Comparative Histology of Certain California Boletaceae.

### COLUMBIA UNIVERSITY

Arthur Percival Tanberg. Experiments on the Amylase of *Aspergillus Oryzae*.

Arthur Waldorf Spittell Thomas. The Influence of Certain Acids and Salts upon the Activity of Malt Amylase.

### UNIVERSITY OF NEBRASKA

Richard Hans Boerker. Ecological Investigations with Certain Forest Trees.

Clarence Jerome Elmore. The Diatoms (Bacillarioideae) of Nebraska.

### YALE UNIVERSITY

Isaac Faust Harris. Chemical and Physiological Studies of the Castor Bean and Soy Bean.

Henry Daggett Hooker, Jr. Thermotropism and Hydrotropism.

### BROWN UNIVERSITY

Benjamin Samuel Levine. The Removal of Natural Impurities of Cotton Cloth by Action of Bacteria.

### CATHOLIC UNIVERSITY

Daniel Da Cruz. A Contribution to the Life History of *Lilium tennifolium*.

### HARVARD UNIVERSITY

Guilford Bevil Reed. Studies in Plant Oxidases.

### INDIANA UNIVERSITY

Fermen Layton Pickett. *Arisaema triphyllum*. A Biological Study.

### UNIVERSITY OF MICHIGAN

Adrian John Pieters. The Relation between Vegetative Vigor and Reproduction in Some Saprolegniaceae.

### UNIVERSITY OF WISCONSIN

Howard Edward Pulling. The Movement of Water in Aerated Soils.

D T. MacDougal.

Miss Lucy E. Cox, of Graystoke Place Training College, London, has written a brief but excellent Experimental Plant Physiology for Beginners (Longmans Green and Company, 1915). The book is devoted solely to the description and discussion of some 69 experiments, all of which are simple, to the point, and capable of being performed with inexpensive equipment. The experiments are chiefly along the familiar lines but are not without touches of originality, especially with regard to the simplification of apparatus. It is unfortunate that a book for beginners should allude to "the breathing of plants." The usual elementary course in plant physiology is so largely concerned with the mere externals of plant activity that it is well worth while not to get them involved in analogies with the externals of animal functions.

Prof. Edward A. White, of Cornell University, has contributed to the Rural Text-Book Series a volume on the Principles of Floriculture (Macmillans, 1915). Every phase of commercial floriculture is treated, from the construction and heating of greenhouses to the shipment and sale of plants and cut flowers. The proper handling and propagation of plants, the preparation of soil, the proper control of temperatures, and the elimination of disease are among the numerous topics which are treated in a thorough and scientific manner.

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